

*A Semi-Monthly Technical Newspaper*

# **Metallurgical & Chemical Engineering**

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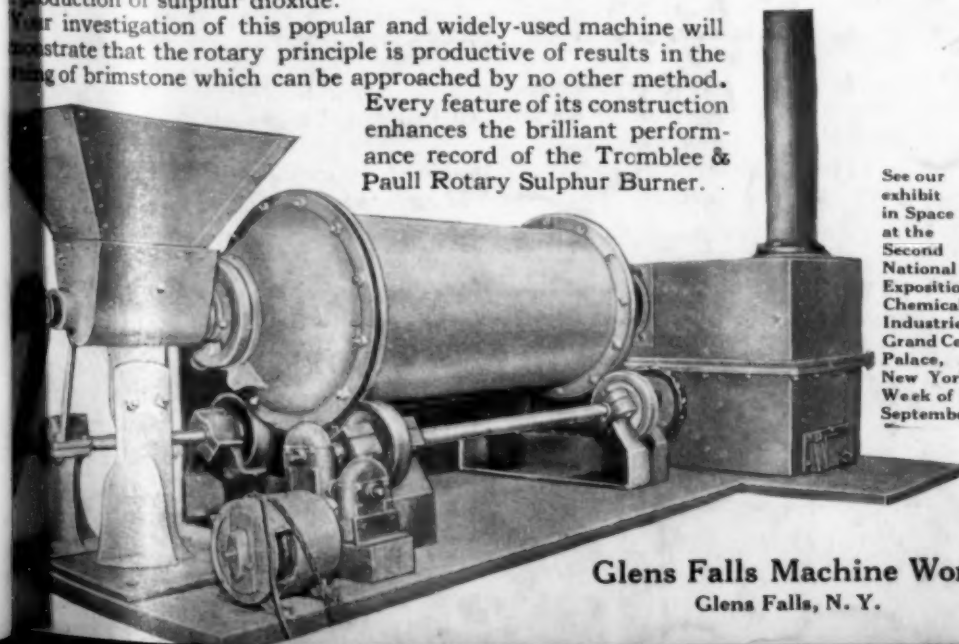
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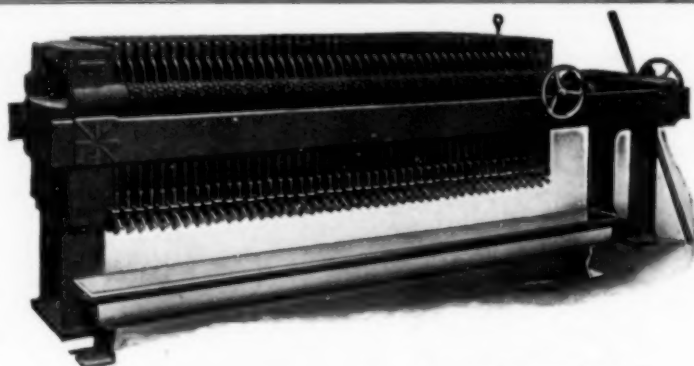
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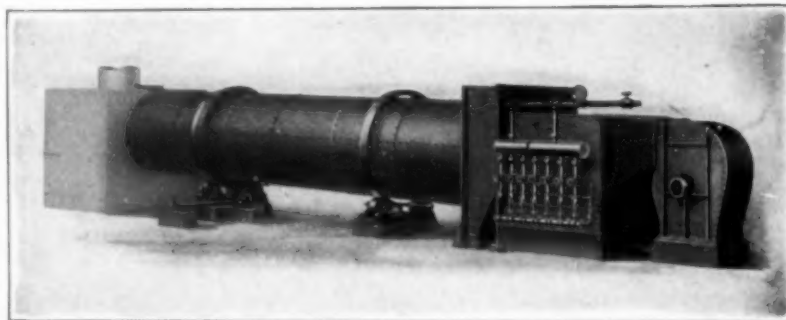
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## Who Produces the Metals?

The national advantage of holding premier rank among the world's metal-producing countries has been accentuated by the war. To both belligerent and neutral nations the control of the output of any metal has become an important asset, either through supplying domestic needs or by increasing revenue through sales to neighbors less fortunately situated. The international scramble for metals has directed attention most forcibly to the sources of the world's metal supply and has brought into prominence some of those that hitherto have been obscure or relatively unimportant.

Among precious metals, 60 per cent of the world's production of gold is controlled by Great Britain, mainly in South Africa and Australasia. This, together with the further fact that less than 1 per cent of the world's gold comes from European countries, has undoubtedly had a great economic effect in the conduct of the world's business during the war. The United States holds second rank in the production of gold, but first in the case of silver, producing about 30 per cent of the world's total. Under normal conditions Mexico would be a close second, with Canada, Australasia and Germany following. Russia is unquestionably the leader in platinum, as no new source has appeared comparable with the placers of the Urals. Colombia is next in importance to Russia, but, besides these two countries, the others, including our own, make but nominal output.

In pig-iron and steel the United States easily holds first rank, with an average production in recent years of about 40 per cent of the total. Germany follows with about 25 per cent. The United Kingdom is third, and France and Russia divide fourth place.

The pre-eminence of the United States also becomes apparent when considering the common base metals—copper, lead and zinc. Of late years we have produced about 55 per cent of the world's output of copper. In 1913 the next nearest competitor, Japan, turned out only 7 per cent of the whole, which clearly demonstrates our own position. Chile, Australasia, Spain, Mexico, Germany and Canada follow with minor percentages. With regard to lead our position is not so strong, though we still lead other countries with a production of about one-third the total. Spain takes second place, with about one-fifth, with Germany and Australasia following. Mexico has held a stronger position than she now occupies, having produced more than one-tenth of the world's output during the period 1908-1911. In spelter production we were credited in the years 1909-1913 with slightly over 30 per cent of the whole. It is greater at the present time, due not only to increased production at home, but also to enforced curtailment abroad. Germany, which for years has distilled the



major portion of zinc concentrates from Australia, has been a very close second during this period, but has not quite equalled our output. Belgium was third with about 20 per cent, and the three countries together accounted for over 80 per cent of the world's spelter. France, Spain and Great Britain have been in minor positions.

Among the minor metals our position is not so prominent. In quicksilver production, Spain, Italy and Austria all surpass us in the order named, Spain producing more than twice as much as the United States. Since 1908 China has led in antimony, producing from two to three times as much as France, which holds second place. Practically all the antimony metal used in the United States is imported from European smelters, our own production being confined to that contained in antimonial lead. Our position is more favorable with regard to aluminium. Estimates of the world's output for 1914 credit the United States with almost half the total; France about one-seventh; Switzerland about one-eighth. Great Britain, Canada, Norway, Austria-Hungary and Italy provide the balance. In the case of nickel we again lead, through our refining of Canadian mattes, but not from treating domestic ores. New Caledonia is the only important competitor of the Sudbury district, Canada, in the production of nickel.

When it comes to the less common metals like molybdenum and tungsten, we realize the world's dependence on relatively obscure sources, though greater domestic production might be stimulated by unusual conditions. No commercial production of molybdenum was reported in the United States in 1914, and the world's principal supply came from Australia. Norway also was an important producer and Canada had made some production. During the past year both domestic and Canadian production has been stimulated. In tungsten we hold a more important place, being second to Burma, which took the lead in 1912. For the period 1912-1914 we produced about 14 per cent of the tungsten of the world, while Burma is credited with 18 per cent.

On the whole, the position of the United States is seen to be an important one. Of the thirteen metals considered, we hold first rank in the production of seven and second in the case of two. In the balance our output is of minor importance, if not negligible.

### Congress and Technical Affairs

Consider the Congressman, how he votes. Occasionally it seems almost as though he knew not, neither did he think. And yet the engineer with all his knowledge is not clothed with the political power of one of these. All of which points a double moral: the necessity of the education of our law-makers in technical matters, which can be accomplished only through greater activity of engineers in the realm of public affairs. Too long has the engineering profession held aloof from those who make our laws and run our government, forgetting that much of the business of state is concerned with problems in organization, management and economics, for which successful engineers should be well fitted.

The fault, when such exists, lies not altogether with public servants, many of whom would lend a willing ear to sound advice on technical matters. Never was a time so propitious for such advice as the present, when public officials are called upon to legislate on matters affecting our industrial growth and welfare, the technique of which is best appreciated by scientists and engineers.

In our last issue, for example, we called attention to the intricacies of the several proposals for a protective dyestuff tariff, and showed that while progress has been made toward an intelligent consideration of this most important matter, it may yet fail of the full measure of attention it demands. And who so well qualified to point the way, avoid the pitfalls and prevent the passage of an abortive half-measure as those who know the technical phases of the industry?

Recently the subject of scientific management received consideration at the hands of Congress in such a manner as to elicit caustic criticism and ridicule from layman as well as engineer. The House passed a bill forbidding time and motion studies on government employees, and prohibiting the adoption of any scheme of remuneration involving bonuses or premiums for excellent work. This is a sad and disgusting spectacle, considering the truly remarkable achievements of scientific management and organization in various industrial lines. It is typical of the manner in which Congress plays politics with matters that should receive intelligent and broad-minded treatment. Instead of welcoming the possibility of placing the Government's business on a basis of efficiency, Congress yields to political pressure, throws a sop to a prejudiced faction, and holds departmental work to the dead level of mediocrity. At a time when private business is being forced to study efficiency and the whole country realizes the necessity of such action, and when one of the candidates for President is talking about "America Efficient," Congress exposes its own inefficiency by putting a spoke in the wheel of progress. Popular impression prevails that governmental departments are not on an efficient basis, and engineers can render a service to the country by expressing that opinion in a manner so forceful as to show Congress the light.

In matters more vital to the mining and metallurgical industries Congress acts with even less discretion. The recent proposed tax on copper for the purpose of raising revenue is a case in point, showing how illogically and superficially a profound subject may be approached. Apparently sensing a popular impression that copper is a highly profitable constituent of war munitions, and without first establishing a broad, fundamental, economic basis for raising revenue in an equitable manner, Congress singles out copper for taxation and gives itself over to class legislation of the wildest sort. If the storm of protest that has been aroused does not call the national legislature to its senses, it is indeed immune to criticism. Such unfair taxation as is proposed in the case of copper can be charged only to astounding ignorance of conditions. Admitting that taxation for revenue is a tremendous prob-



lem, there is the greater need to stop, look and listen before proceeding blindly.

We presume that instances might be multiplied to prove political inadequacy in dealing with technical affairs. Congressional proposals for the revision of the mining law, and political interference with the work of our technical bureaus furnish other examples. We need more representatives of science and industry in Congress, and fewer politicians and lawyers. Then, perhaps, the Government will conduct its business in a more efficient manner and without regard to political expediency. In the meantime, with all its unwise proposals in technical matters, Congress continues to caress the pork barrel with wonted satisfaction, unwilling to play its part in economy and efficiency. The situation calls for intelligent help, which it becomes the duty of engineers to offer.

### The Bureau of Mines' New Stations

By an act of Congress passed over a year ago the Bureau of Mines was authorized to establish ten experiment stations for mining and metallurgy, in addition to the five already existing at Pittsburgh, Denver, Salt Lake City, San Francisco, and Urbana, Ill. It was provided that not more than three of the new stations should be established in any one year, and it was expected that their work would be supplemented by appropriations from the States in which they should be located. The first three of these stations are to be established this year, and the sum of \$25,000 is appropriated annually for each of them.

Two of the new stations have been definitely located at Fairbanks, Alaska, and Tucson, Arizona. The third will be placed somewhere in the Northwest, in Washington, Idaho or Montana, and Director Manning is now on a trip of inspection to decide the location. We understand that the selection will be made wholly with a view to the best service that can be rendered to the industry by the Bureau, and that political pressure or flattering offers of local assistance and cooperation will receive minor consideration. The station may go to Butte, Seattle, Moscow or Pullman, each of which is reported to be bidding actively for the director's favorable consideration.

The Arizona station will be at Tucson where the State school of mines is situated, and co-operative work will be carried on by the two organizations. Similar arrangements now exist at Salt Lake City, Urbana and Golden, where the Universities of Utah and Illinois and the Colorado School of Mines, respectively, have co-operative agreements. The station at Golden was recently removed there from Denver and is now occupying an entire building placed at its disposal by the Colorado School of Mines.

When it was first proposed to establish ten new stations, each with an annual appropriation of \$25,000, we opposed the plan because we believed a single station centrally located, with \$250,000 per annum at its disposal could do more effective work. It seemed, furthermore, that ten stations must inevitably duplicate equipment and staff to an alarming degree. Apparently it

was impossible to put such an economic measure through Congress, and Dr. Holmes, who was then director of the Bureau, made the best of the situation and accepted the ten stations as an alternative.

This plan is now going into effect and a definite line of work is being assigned to each station so that duplication of work, at least, is being avoided. Thus the Urbana station appropriately confines its work mainly to coal; Tucson will study problems relating to copper; Golden is devoted to investigations of the rare metals, and so on. The location of stations at State schools is a policy that should be fruitful of results for both parties to the arrangement. If the States make appropriations commensurate with the sums expended by the Bureau, double the amount of work can be accomplished at half the cost to either party. As a rule the schools are able to offer housing, equipment, laboratory and library facilities that save the Bureau a large sum of money and leave its funds available for research work.

In a measure the whole scheme of separate stations may be considered experimental, and the future policy of the Bureau probably will be determined by the success or failure of the plan. If, after a few years' trial, it is found inexpedient, the separate stations may be combined at a central point. In the meantime the whole industry, and particularly the States concerned, should make a consistent effort to support the Bureau in getting the best possible results.

### Tungsten

According to statistics gathered by the U. S. Geological Survey, the tungsten production of the United States during the first six months of 1916 exceeded the production of this or any other country in any previous twelve months. The output was equivalent to about 3290 short tons of 60 per cent  $WO_3$  concentrates, and was valued at \$9,113,000. If the tonnage was remarkable, the value was even more so. The last six months of the year probably will show a decrease in production and assuredly a marked reduction in value, for it seems certain that so spectacular a market for tungsten will not be experienced in many years, if ever.

Colorado has regained first place as a tungsten producer and Boulder is again the premier district. California is second, with Nevada and Arizona following. Nearly all of the western States reported some production. But if reports regarding a new tungsten discovery in Nevada are confirmed, Colorado and other States may be relegated to minor positions. A deposit remarkable both for its extent and grade of ore is now being developed and a concentrating mill is under construction. In addition to ore of milling grade, large quantities of shipping ore are reported.

The situation in Colorado has become more stable, and operators are wisely turning their attention to the production of such finished products as ferrotungsten, tungstic acid and metal, instead of marketing raw concentrates. Tungstic acid has been produced for some time by at least two concerns, and improved methods of treatment are reported as a result of the research that has been under way for the past year.

## Readers' Views and Comments

### The Distribution of Silver Between Metallic Lead and Litharge—Containing Slags

*To the Editor of Metallurgical & Chemical Engineering*

SIR:—I have been much interested in the article by Prof. Boyd Dudley on "The Distribution of Silver Between Metallic Lead and Litharge-Containing Slags," which appeared in the issues of June 1 and 15. His research shows clearly among other things: (a) the advantage of using as little litharge-containing slag as consistent with good fusions; (b) the reason why a long, slow fusion of excess litharge slag, ending at a moderate temperature, gives a better silver result than a quick, hot fusion; (c) that the reduction of a small lead button in the crucible, resulting in a high silver concentration, will be accompanied by a high slag loss, which may, however, be partly balanced by a lower cupellation loss. These facts have in the past been more generally accepted than understood.

The question whether silver in assay slags is dissolved or oxidized is interesting, but difficult of proof one way or the other. The slags obtained in commercial copper matte smelting, to which Professor Dudley has referred, probably hold a part of their silver as oxide (*E. & M. J.*, Vol. 100, pages 215, 263, 305). If excess litharge flux be used for silver determinations, fairly good results may be obtained by performing the fusion in a strongly reducing atmosphere, which may be easily obtained by filling several crucibles with soft coal and placing them in the muffle with the fusions. This should not affect the solubility of silver in litharge, but might reduce silver oxide to some extent. Oxidation of silver is also suggested by the lower slag loss of gold, which is not readily oxidized. Probably oxidation and reduction both take place; if so, Professor Dudley's work shows that they obey similar laws.

Yours truly,

FRANK E. LATHE.

The Granby Consolidated Mining, Smelting & Power Co., Ltd.,  
Grand Forks, British Columbia.

### Rapid Analysis of White Bearing Metals for Copper and Lead

*To the Editor of Metallurgical & Chemical Engineering*

SIR:—The following method for the rapid analysis of white bearing metals for copper and lead has been used by me many times and I have found it very rapid and at least as accurate as any of the other technical methods for the determination of these two elements.

Take 1.0 g. sample in a 150 c.c. beaker, add a pinch of tartaric acid and 20 c.c. aqua regia, and heat to solution. Remove from the hot plate, rinse into 50 c.c. 25 per cent NaOH contained in a 400 c.c. beaker, add 15 c.c. 25 per cent Na<sub>2</sub>S and heat just to boiling over the flame, keeping the beaker in constant motion. Remove from the flame, allow to settle a moment, and filter through an 11 c.m. hard paper (with suction). Wash four times with dilute hot Na<sub>2</sub>S solution. Transfer the paper and ppt. to a 250 c.c. beaker, add 10 c.c. conc. HNO<sub>3</sub>, boil until the paper is disintegrated. This should be carried on over a good flame. Now add 5 c.c. conc. H<sub>2</sub>SO<sub>4</sub> and boil until the solution has turned black. Add 3 c.c. conc. HNO<sub>3</sub>, and again boil until the solution turns dark. Repeat alternate additions of HNO<sub>3</sub> and boiling until the solution goes down to SO<sub>2</sub> fumes without any appreciable darkening. Remove from the flame, cool with the air

jet, dilute with cold aq. to 50 c.c. and if the percentage of lead is below ten, add an equal volume of grain alcohol. Stir well, allow to settle a moment and filter through an 11 cm. double paper. Determine the Cu either electrolytically or by iodometry. Determine the lead as sulphate, or by one of the standard volumetric methods. An analysis may be completed in one to one and a quarter hours.

Hoping this may be of service to your readers as it has been to me, I beg to remain,

W. L. JACKSON.

E. C. Atkins & Co.,  
Indianapolis, Ind.

### Western Water-powers and Electrochemical Industries

*To the Editor of Metallurgical & Chemical Engineering*

SIR:—Your comment in the issue of July 1, upon the article on the electrochemical possibilities of the Pacific Coast, by Mr. Beckman, in the same issue, furnishes incentive for discussion in the statement that "It would be plain foolishness to think that the abundant and cheap water-powers of the Pacific Coast could be made to supply the principal markets now supplied by the electrochemical industries of Niagara Falls . . . the manufacturing districts of the East and Middle West."

On second thought, is this statement entirely consistent with the statements of the advocates of Niagara Falls as against the rest of the country, that "large industries are being driven to Europe and to Canada on account of the famine of power which exists at Niagara Falls?"

Is it not a fact that the prices of electrochemical products and metals are based on seaboard deliveries, generally?

It will hardly be contended that there is any less tendency now than heretofore for the broad chemical and metal industries to seek the seaboard, around the world. It would, therefore, appear to be still true that the Atlantic, Gulf and Pacific seaboard are quite as important market and transportation factors as the Great Lakes.

Specifically, we would cite the case of aluminium, the most important electrochemical industry, and the one consuming the most power. It is hardly fair to contend that Niagara Falls and Canada is the natural and only feasible region for the economical production of aluminium; the ore going from Arkansas to East St. Louis for concentration, thence to Niagara Falls and Canada for reduction, and the metal again returning to St. Louis and to New York—the centers of population and manufactures of the Middle West and of the East, to which you refer—and wherein the ores and other considerable materials consumed in the production of aluminium, and the metal to market, are carried almost entirely by rail, at three to ten times the cost of water transportation.

The Great Lakes are certainly not a controlling factor in this electrochemical industry.

Wherein would really cheap water-power, and aluminium ores and carbonate of soda, and electrode carbon, within a few miles of seaports with cheap fuel, on the Pacific, be handicapped in comparison with Arkansas and Niagara Falls and Canada?

F. LANGFORD.

Eureka, California.



## Metallurgical Plants of Arizona

### A Brief Summary of the Extent of Metallurgical Practice in Arizona, and the Itinerary of the Tour of the American Institute of Mining Engineers

THE meeting of the American Institute of Mining Engineers in Arizona, Sept. 18 to 24 inclusive, directs attention to the important place which that State now occupies in mining and metallurgy. It holds first place in production of copper, having excelled Montana in that respect. It contains also within its borders, though not on the Institute route, the newest and most important gold-mining district, Oatman, where new metallurgical plants are in course of erection. In fact, general progress in mining, smelting, concentrating and cyaniding in Arizona has been so rapid and interesting that it holds unusual attraction for engineers who are fortunate enough to find time for even a brief visit to the principal districts. Technical skill is represented in the highest degree among the engineers who are in charge of operations, and they are not lacking in those qualities of friendliness and generosity toward the profession that make for progress through a courteous exchange of information. These features, combined with the fact that the Institute's president, Dr. L. D. Ricketts, has been a leading factor in the development of mining and metallurgy in Arizona, make the prospective meeting most opportune.

A special train will be at the disposal of the Institute party, leaving New York Thursday, Sept. 14, and arriving at El Paso, Tex., Sunday, Sept. 17. From El Paso the itinerary includes continuous visits for a week to the principal mining and metallurgical districts of Arizona, with a short stop in New Mexico, ending at the Grand Canyon on Sunday, Sept. 24. A brief outline of the tour follows; full details can be secured from Institute headquarters.

**Monday, Sept. 18.**—Mines of the Chino Copper Company and mill of Empire Zinc Company, Santa Rita, N. M. Mill of the Chino Copper Company, Hurley, N. M.

**Tuesday, Sept. 19.**—Reduction works of Copper Queen Consolidated Mining Company and of Calumet & Arizona Mining Company, Douglas, Ariz. Technical sessions on smelting and leaching.

**Wednesday, Sept. 20.**—Mines of the Bisbee district. Technical session on mining and geology.

**Thursday, Sept. 21.**—Mines and reduction works of Old Dominion Copper Company, Globe. Technical sessions on concentration, flotation and fine grinding.

**Friday, Sept. 22.**—Reduction works of International Smelting Company and mills of Inspiration Consolidated Copper Company and Miami Copper Company, Miami. Technical session on mining and smelting.

Side trips can be arranged from Globe to mines of the Ray Consolidated Copper Company at Ray, or over Apache trail to Roosevelt dam. The main party will travel via Phoenix to the Grand Canyon, where Sunday will be spent, after which the special train will return to New York.

The visits to mines and metallurgical plants, and the technical sessions will be interspersed with social functions, which will add pleasure and profit to the trip.

#### Summary of Metallurgical Plants

That those who plan to attend the meetings may have an idea of the extent of metallurgical practice in Arizona and a bird's-eye view of the processes and equipment that may be seen, not only on the Institute route but elsewhere in the State, we have prepared the accompanying map and data. The latter have been supplied mainly by officials of the different companies, or compiled from sources considered reliable. The order of their presentation is with reference to, first, the Institute main itinerary and scheduled side trips, and, second, other metallurgical centers in the State. Numerals and letters refer to locations on the map, the former indicating the Institute route and the latter other metallurgical centers.

comparing map and data. The latter have been supplied mainly by officials of the different companies, or compiled from sources considered reliable. The order of their presentation is with reference to, first, the Institute main itinerary and scheduled side trips, and, second, other metallurgical centers in the State. Numerals and letters refer to locations on the map, the former indicating the Institute route and the latter other metallurgical centers.

#### Copper concentrating mills:

- B Arizona Copper Company, Clifton.
- F Consolidated Arizona Smelting Company, Humboldt.
- B Detroit Copper Mining Company, Morenci.
- 3 Inspiration Consolidated Copper Company, Miami.
- D Magma Copper Company, Superior.
- 3 Miami Copper Company, Miami.
- 3 Old Dominion Copper Mining & Smelting Company, Globe.
- X Ray Consolidated Copper Company, Hayden.
- B Shannon Copper Company, Clifton.

#### Copper reduction works:

- C American Smelting & Refining Company, Hayden.
- B Arizona Copper Company, Clifton.
- 1 Calumet & Arizona Mining Company, Douglas.
- F Consolidated Arizona Smelting Company, Humboldt.
- 1 Copper Queen Consolidated Mining Company, Douglas.
- B Detroit Copper Mining Company, Morenci.
- 3 International Smelting Company, Miami.
- 3 Old Dominion Copper Mining & Smelting Company, Globe.
- B Shannon Copper Company, Clifton.
- Z United Verde Copper Company, Clarksdale.

#### Cyanide mills:

- A Commonwealth Mining & Milling Company, Pearce.
- Z Copper Chief Mine (Hayden Development Company), Jerome.
- G Gold Road Mines Company, Goldroad.
- G Tom Reed Gold Mines Company, Oatman.
- G United Eastern Mining Company, Oatman.
- E Vulture Mines Company, Wickenburg.

#### On the Institute Route

1. **Douglas.** Calumet & Arizona Mining Co. smelting plant was completed in 1913, and contains two 48-in. by 40-ft. blast furnaces, four 19-ft. by 100-ft. reverberatory furnaces, twelve seven-hearth roasters 21-ft. 6-in. diameter, and six Great Falls type basic-lined converters. The plant is treating 3000 tons of charge per day and produces 7,000,000 lb. of copper per month. In addition to the smelting plant at Douglas, the company has under construction at Ajo a copper leaching plant which will have a capacity of 5000 tons per day. This plant is expected to be in operation early in 1917, and will be one of the most interesting examples of copper leaching in this country, producing 36,000,000 lb. of copper per year. Coarse crushing will be done with gyratories to about 3½ in., and with Symons disk crushers to ¼ in., at which size leaching will be done. Eleven lead-lined leaching vats will be 88 ft. square by 15 ft. deep, with an aggregate capacity of 5000 tons. Sulphur dioxide will be used for reduction of ferric iron





in the solution, and copper will be precipitated electrolytically.

The Copper Queen Consolidated Mining Company's smelting plant includes ten blast furnaces, sixteen six-hearth McDougal roasting furnaces, three oil-fired reverberatory furnaces and seven 13-ft. upright basic-lined converters. In 1915 the average tonnage smelted per blast-furnace day was 363.5; average product per roaster day, 47.5 tons of calcine; average daily reverberatory tonnage was 338.7, and copper bullion was made at the average rate of 32.6 tons per converter per day. Recent improvements made in overcoming dust losses at this plant are the subject of a paper to be presented at one of the Institute meetings.

2. Bisbee. Copper mines of the Copper Queen Consolidated Mining Co. will be open to inspection.

3. Globe-Miami District. The Inspiration Consolidated Copper Co. produces only copper concentrates, the ore containing small amounts of gold and silver, but too little to bring a commercial return to the company. The ore is a chalcocite disseminated through a schist gangue. The rate at which they are mining and milling at present is 16,000 tons per day, the largest output of mine to date for one day being 19,600 tons. The output of copper for the past two months has been 10,500,000 lb. per month. The run of mine ore is ground to pass a 48-mesh screen, after which it is subjected to flotation treatment, the sand tailings from flotation being further treated on concentrating tables. The concentrates are partially dewatered in Dorr tanks, and later put through Oliver filters. These concentrates are shipped to the International smelter, located 1 mile from the Inspiration mill, where they are smelted in reverberatory furnaces, the matte being treated in converters of the Great Falls type. The product is shipped to the Raritan, N. J., works of the International Smelting Company. Before going to the reverberatory furnaces the concentrates are put through a drying plant of Wedge furnaces. This drying plant is equipped with Cottrell dust collectors, and the converter gases are also passed through another Cottrell dust collector.

The International Smelting Co., which completed its plant at Miami in May, 1915, is a subsidiary of the Anaconda Copper Mining Company. It was designed, primarily, to treat the concentrates of the Inspiration Consolidated Copper Company and the Miami Copper Company. About 70 per cent of this material is a flotation product which is delivered to the plant in the form of a soft mud. After passing the dryers, it takes the form of an impalpable powder, so the handling of the original material and preventing mechanical loss later is rather difficult.

The plant has four principal metallurgical departments: I. Receiving, sampling, bedding and reclaiming. II. Drying. III. Reverberatory smelting. IV. Converting.

All fluxes and secondaries are crushed to at least  $\frac{3}{4}$  in., and the proper mixture for smelting is made in the bedding bins.

Five fire-hearth Wedge mechanical roasters, 22 ft. 6 in. in diameter, burning oil, are in operation for drying and heating the charge. As it is not profitable to eliminate any of the sulphur, the temperature here is kept rather low.

Two oil-fired reverberatories, 21 ft. by 120 ft., with mechanism for charging the entire tonnage at the side walls, are in operation. Three 713-hp. Stirling boilers, in parallel, are used with each furnace. An extra furnace is in reserve.

At the converter plant are five stands with the 12-ft. Great Falls type of shells, two straight-line casting machines, and a McGregor skull-breaker.

The solid charge handled by furnaces per day is 1125

tons, 877 tons of which is concentrates. The copper content of the new material is 281.5 tons, with 9 ounces of gold and 780 ounces of silver, producing 275 tons of copper, 8 ounces of gold and 700 ounces of silver.

The property of the Miami Copper Company, located 7 miles west of Globe, Ariz., comprises an ore body of chalcocite disseminated in schist, a combined water and flotation concentrator, a concentrate-handling plant, a reclaimed-water plant and a fuel-oil power plant. The current production is about 50,000,000 lb. of copper per annum.

The ore body is composed of Pinal schist, intermixed with granite porphyry and overlain by about 200 to 300 ft. of silicified capping. The mineral occurs as partially oxidized chalcocite finely disseminated throughout the schist and porphyry. The present ore reserves are about 18,000,000 tons of high-grade sulphide ore, averaging about 2.40 per cent copper and 17,000,000 tons of low-grade primary ore. Mining is conducted by underground workings, using shrinkage stoping and top slicing methods. The ore is hoisted by balanced Kimberly skips of 7-ton capacity from a depth of 400 and 500 ft.

The concentrator is of steel and concrete construction, and comprises a coarse-crushing plant and six independent grinding and concentrating sections, with an initial capacity of 3000 tons of ore per twenty-four hours, which has been increased to 5000 tons. Coarse-crushing is performed by Kennedy gyratory crushers and Traylor rolls, and fine grinding by Hardinge conical ball mills. Concentration is performed with Deister sand and slime tables, followed by flotation, using Callow flotation cells. Ratio of concentration is about 25 to 1.

Water for concentration is obtained from the Old Dominion mine, 7 miles distant, and is partially reclaimed by means of sixty-four concrete settling tanks. About 75 per cent of the water used in milling is thereby reclaimed.

Concentrates are laundered to a concentrate-handling plant, comprising twelve vacuum dewatering tanks. Belt-conveyors communicating with these tanks transfer the concentrates, after drying, to 60-ton steel concentrate cars for shipment to the neighboring plant of the International Smelting Company.

The power plant, located adjacent to the town of Miami, is a steel and concrete structure, and comprises a boiler plant containing five batteries of 600-hp., oil-fired boilers, and an engine house containing three 1000-kw., triple-expansion engines, two 4000-cu. ft., triple-expansion air compressors, and condensing apparatus.

The Old Dominion Copper Mining & Smelting Co. has a new 700-ton concentrating mill which was put in operation about two years ago. As a result of the improvements made in the new plant the percentage recovery of copper was raised from 73.55 in 1914 to 85.27 in 1915. Grinding is done with Hardinge conical and Marathon mills; pulps are classified in Deister cone classifiers and concentrated on Deister tables and Senn pan-motion vanners. A 16-cell, 300-ton Minerals Separation flotation machine has been in use for some time, and other types of flotation apparatus are being tested. An Oliver filter is used to dewater the flotation concentrate. The smelting plant consists of blast furnaces only. The Great Falls type of basic-lined converter is used, and a remarkable cost record has been made. One shell was in service continuously for over thirty months, producing 70,860,000 lb. of copper bullion. The lining cost was  $5\frac{1}{2}$  cents per ton of bullion, as compared with a cost of \$1.80 per ton with the old acid-lined shells. A feature of the power plant is a Diesel oil engine and generator.



**X. Ray.** Ray Consolidated Copper Co. mines may be visited on a side-trip from Globe. The company's mill is at Hayden, near the smelter of the American Smelting & Refining Company.

**Z. Jerome-Clarkdale District.** This region of Arizona is prominent through the operations of the United Verde Copper Co., with mines at Jerome and a new smelting plant at Clarkdale. The capacity of the Clarkdale plant is about 3000 tons of charge daily, and production amounts to 5,000,000 pounds of copper per month, in which is contained a small amount of gold and silver. The principal metallurgical departments are (1) crushing and sampling; (2) roasting; (3) blast-furnace and reverberatory smelting; (4) converting. The roasting equipment comprises eight 6-hearth Wedge roasters, 21 ft. 6 in. diameter. In the smelting department there are four 48 in. by 320 in. blast furnaces with Giroux hot-blast tops, and three 19 ft. by 100 ft. oil-fired reverberatories. The converting equipment consists of five stands of 12-ft. Great Falls type basic-lined converters. Further data on the operation of this plant will appear in a later number of this journal.

The Copper Chief mine, operated by the Hayden Development Co., near Jerome, has a new cyanide mill of 125 tons daily capacity. Ore is crushed by Blake crusher, ball and tube mills, the latter in closed circuit with a Dorr classifier. Continuous counter-current decantation is practiced, using Dorr agitators and thickeners with Oliver filters at the end of the system. The customary zinc boxes are used for precipitation, and the product is melted in a Steele-Harvey furnace. The entire mill is electrically driven by power obtained from the Arizona Power Company's plant at Fossil Creek.

#### Other Metallurgical Centers

**A. Pearce.** The cyanide mill of the Commonwealth Mining & Milling Co. is located here. Ore is crushed first in gyratories and then thirty 1550-lb. stamps. Classification is given in Caldecott cones and Dorr classifiers, and further grinding is done in Hardinge conical mills and tube-mills. Continuous counter-current decantation is practised, using Dorr thickeners and Pachuca agitators. Oliver filters and Merrill zinc-dust precipitation complete the equipment.

**B. Clifton-Morenci-Metcalf District.** Three large copper companies operate in this important district. The Arizona Copper Co. has concentrating and smelting plants which will be the subject of a paper to be presented at one of the technical sessions.

The Detroit Copper Mining Co. produces about 19,000,000 pounds of copper annually. Run of mine ore is reduced by one Gates gyratory crusher and two Symons disc crushers to 1-in. size. This product is fed at the rate of 1500 tons to the two-unit concentrator.

The mill feed is reduced by rolls to pass a four-mesh screen and is then treated to a succession of wet concentrations as follows:

Total mill feed through four-mesh is treated on Butchart national tables, the tailings of which are deslimed in shovels. The fine product (slime) of these shovel wheels is primary slime. The coarse product is reduced to 1½ millimeter by means of Monadnock and Marathon mills. The product of these mills is separated by means of Dorr classifiers into coarse sand, fine sand and slime; the coarse sand is treated on Butchart National tables, the fine sand on Frue sand vanners, and the slime overflow, united with primary slime mentioned above is treated by flotation machines of the Rork type.

Flotation reject is cleaned up by a system of Frue

sand vanners. Total mill concentrates are dried by vacuum tanks and shipped to smelter. The tailings are dewatered in Dorr tanks and the clear water returned for further use.

Concentrates are delivered to the smelter which consists of one 500-ton blast furnace. The matte is then delivered to three barrel-type converters. The product is sold as casting copper.

The Shannon Copper Co. is the third concern operating in this district and has a copper concentrating mill and smelting plant.

**C. Hayden.** The American Smelting & Refining Co. operates a smelting plant of 25,000 tons monthly capacity, producing 8,000,000 lb. blister copper per month. The bullion contains some gold and silver. The principal departments are sampling, roasting, reverberatory smelting and converting. The equipment consists of eight McDougall roasters, two reverberatory furnaces, two Peirce-Smith and one Great Falls type converters and one Walker casting machine.

In the same vicinity is the concentrating mill of the Ray Consolidated Copper Co., which is about 18 miles distant from the mines at Ray. The present capacity is 10,000 tons per day, and the principal metal is copper, although the ore contains a small amount of silver. Coarse crushing to 1-in. size is done at the mine and further reduction is made at the mill with Garfield rolls and Chilean mills. Concentrating equipment consists of Garfield roughing tables, Wilfley tables and slime vanners.

**D. Superior.** At this point the Magma Copper Co. is conducting experimental operations in the concentration of copper and zinc ores. The copper concentrator is handling about 200 tons of ore per day which is delivered from the mine by a Bleichert aerial tramway. A variety of crushing and grinding machines are in use, comprising Blake crusher, Symons 24-in. disc crusher, Marcy ball-mill and Chalmers & Williams tube-mill. The crushed pulp is concentrated over roughing tables, and by flotation in Callow pneumatic cells. The tailings from the latter are reconcentrated on Wilfley tables. The 50-ton zinc concentrator uses the same types of crushing and grinding apparatus, Callow flotation cells and Deister double-deck tables.

**E. Wickenburg.** The cyanide mill of the Vulture Mines Co. gives some distinction to this point in Arizona by reason of having been one of the first to make a commercially successful use of the continuous counter-current decantation system of cyaniding. More modern mills have since used the process in greater refinement. This plant is small, having a capacity of but 75 tons per day.

**F. Humboldt.** The Consolidated Arizona Smelting Co. has copper smelting and concentrating plants at this place. The concentrating equipment and practice were discussed in this journal, Dec. 1, 1915, p. 897. Data on reverberatory smelting appeared Jan. 1, 1916, p. 33. Improvements in both plants have been made since that time, increasing capacity and efficiency. The introduction of flotation, together with other changes in the mill, increased recovery of copper by more than 20 per cent over the best saving previously made with jigs, tables and vanners.

The principal features of the mill, described in the article mentioned above, are grinding with Hardinge mills and the use of the Minerals Separation flotation process. The smelting equipment consisted of one 7-hearth Wedge roaster, 21 ft. 6 in. diameter; one 19 ft. by 60 ft. and one 19 ft. by 100-ft. oil-burning reverberatory furnaces; two stands of 9 ft. 6 in. barrel-type basic-lined converters.



**G. Goldroad-Oatman District.** This part of Arizona has recently attracted considerable attention by reason of the remarkable discoveries of gold and silver ore in a region where two companies had operated for a number of years. The **Gold Road Mines Co.** has a 350-ton cyanide mill, using stamps and tube-mills for grinding, and continuous counter-current decantation with Dorr thickeners and Pachuca agitators. Precipitation is by means of zinc dust. The **Tom Reed Gold Mines Co.** at Oatman has a similar mill of 200 tons daily capacity, with practically the same equipment. Among the newer mills projected in the Oatman district is that of the **United Eastern Mining Co.** The tentative flow-sheet shows crushing with gyratories, ball-mills and concave mills, the latter in closed circuit with Dorr classifiers. Continuous decantation with Dorr apparatus follows the latest developments in that method of cyaniding, and precipitation is to be done by the Merrill zinc-dust process.

## The Training of Our Captains of Industry\*

BY SIR ROBERT HADFIELD

A good deal has been said, particularly in the last few months, with regard to the training of men on whom rest the responsibility to organize and direct the technical side in great industrial affairs. In my opinion neither the scientific man nor the practical man wholly fulfills the required conditions for the direction of great modern affairs. By the practical man I mean the man who has received a good secondary education, but not special scientific culture, and by the scientific man I mean the man who is completely instructed, but is a stranger to actual experience and practice.

It usually happens that the scientific man is as necessary as the practical man, but neither the one nor the other is a satisfactory organizer, because they do not unite in one head the combination of the two indispensable elements. It is therefore necessary to arrange our educational courses so as to combine the two; in other words, to find a third type of man in whom such knowledge will be united. The solution of the problem is not easy, but it is more than ever necessary that at the present time such a new type should be evolved and developed.

Until quite recently many mistakes were made, either because the scientific man had been installed in view of his special knowledge or, at the other end of the scale, the practical man was given the preference. In a general way neither of these types has been a success.

Industrial operations of every kind, and of an increasingly complex character, are developing every day, and they are also tending to be more and more technical. This is the normal consequence of the extremely rapid progress which every nation is making in the acquisition of knowledge, which in itself is constantly becoming more varied, and yet more specialized.

It is most difficult to map out a program of education which will combine both scientific and practical ideas, especially as the main functions of each of these are sufficiently defined and naturally fall into their respective spheres. The scientist has a satisfactory education in the universities. The practical man is generally contented with an ordinary high school education, and sometimes, as is well known, he has not even had the benefit of this general education.

The scientist can certainly do excellent work in his laboratory, but generally speaking, he will only be able to render these services in this one capacity, because he has not had the opportunity to adjust his theoretical

knowledge to industrial conditions. The practical man also in his vocation is able to do good work, but it is doubtful whether in these days he can ever furnish work of the highest order.

How then are we to obtain this important combination? How can we realize the combination of science and practice? The problem is admittedly most difficult, and the solution of it probably depends in a large measure on the individual character. By means of character and energy the scientist can acquire practical knowledge; that is, he can apply his scientific knowledge to practical questions. In the same way, the practical man can acquire scientific knowledge. Education will certainly help the formation of this mixed type, but it will not be created by education alone. It must be a result either of natural temperament, of faculties developed by force of character, or in certain cases through gifts transmitted by heredity.

Naturally the best path to follow is that of scientific education, but on condition that instruction furnished by practical observation is not neglected.

All things considered, the scientist will certainly be in a better position, but if he does not possess the necessary turn of mind and the natural qualities to which reference has been made, this education which should have given him a great advantage may cause his ruin. It may prevent him from attaining the height of success to which he might have reached by applying his knowledge to practical ends. He remains in the same sphere, and cannot emerge therefrom. Numerous are such cases, and numerous also the instances of non-success among men who are practical, in consequence of their lack of scientific knowledge.

While much has already been done, there is much more to be accomplished in order to succeed in generating the evolution of the type of man required by modern conditions. Many facilities are offered to the practical man by the creation of the numerous and liberally endowed sources and seats of instruction which have been installed in all countries during the last twenty-five years. There has been the work of our universities, also of the departments of applied science attached to those universities, of our schools and technical colleges, of our research laboratories, our societies and technical institutions, and finally our technical press. All these are, in this order of ideas, of capital importance.

The combination of science and practice is of the greatest importance, but it is doubtful whether it can be obtained by education alone. In order to attain the highest degree of success a man requires something even more than education; that is, above all he must show personal application and intuition.

As so much attention is being given to a wider application and more intimate combination of science with industrial research, a few special remarks may be made with reference to this side of the subject, and in this respect attention is specially drawn to the admirable advice given by the late Dr. G. Gore, F.R.S., in his book, "The Art of Scientific Discovery."

Dr. Gore himself did most important research work. For example, it was he who discovered that iron, while cooling from a high temperature—then termed "red heat," now known as the "critical iron changing point"—about 750 deg. C., and under longitudinal strain, suddenly undergoes molecular and magnetic change attended by increase of length at a particular time. This peculiar behavior of iron has been termed "Gore's phenomenon." From Gore's observations of this simple fact eventually sprang the further discovery of Sir William Barrett, F.R.S., with regard to the recalcence of steel, which was further followed up by the late Prof. F. Osmond in France, with such important results.

\*From *The Iron and Coal Trades Review* (London) of June 9, 1916.

Gore shows in his work above referred to that scientific discovery is really no haphazard matter, and that the art can be cultivated. While all may not have the same mental capacity, there are many who, by scientific study, may acquire the art to a greater or lesser degree. There is, of course, some difference between discovery and invention. Gore defines it as follows: "Discovery consists in finding new truths of Nature, while invention consists in applying those truths to some desired purpose." However, for our present purpose the two may be treated more or less on an equality. Gore points out, while he does not maintain, that important discoveries can be made by rule alone; nevertheless the process of scientific discovery can be largely reduced to order and rule. It may be interesting to note the following types of research tabulated by Gore and through which discovery and invention may be attained:

Table by Dr. Gore Showing That Discovery and Invention May be Obtained in Some of the Following Manners:

- (1) Aid to Analogy.
- (2) Hypotheses.
- (3) Analysis and Synthesis.
- (4) Application of—
  - (a) Electricity to bodies.
  - (b) Heat to substances.
- (5) Asking questions and testing such questions.
- (6) Assumptions that—
  - (a) There is certainty of all the great principles of science.
  - (b) Complete homologous series exist.
  - (c) Converse principles of action exist.
  - (d) Certain general statements which are true of one force or substance are true to some extent of others.
- (7) Combined action of many observers.
- (8) Comparisons of—
  - (a) Facts, and collecting similar ones.
  - (b) Collections of facts with each other.
  - (c) The orders of collections of facts.
  - (d) Facts with hypotheses.
- (9) Deducing process.
- (10) Employment of new or improved means of observation.
- (11) Examination of—
  - (a) Common but neglected substances.
  - (b) Effects of forces on substances.
  - (c) Effects of contact on substances.
  - (d) Effects of extreme degrees of force.
  - (e) Extreme or conspicuous instances.
  - (f) Influence of time upon phenomena.
  - (g) Neglected truths and hypotheses.
  - (h) Peculiar minerals.
  - (i) Unexpected truths.
  - (j) Rare substances.
  - (k) Residue phenomena.
  - (l) Residues of manufacture.
  - (m) The ashes of rare plants and animals.
- (12) Extension of—
  - (a) The researches of others.
  - (b) The researches of neglected parts of science.
- (13) Inductive process.
- (14) Investigations of—
  - (a) Exceptional cases.
  - (b) Unexplained phenomena.
  - (c) Classification unexplained.
- (15) Means of—
  - (a) Converse experiments.
  - (b) Hypotheses.
  - (c) "Homologous Series."
  - (d) Instruments of great power.
  - (e) Improved methods of intellectual operation.
  - (f) Measurements.
  - (g) The method of curves.
  - (h) The method of least squares.
  - (i) The method of means.
  - (j) The method of residues.
  - (k) New instruments.
  - (l) Modes of observation.
  - (m) Observations.
  - (n) More intelligent and acute observation.
  - (o) Additional observations by known methods.
  - (p) Periodic functions.
  - (q) More refined methods of working.
  - (r) Repetition of experiments.
- (16) Simple comparisons of facts of phenomena.
- (17) Search for—
  - (a) So-called "Impossible" things.
  - (b) One thing and finding another.
- (18) Subjecting series of forces or substances to new conditions.
- (19) Use of—
  - (a) Known instruments or forces in a new way.
  - (b) Improved instruments.
  - (c) More powerful instruments.
  - (d) Causes by the methods of averages.
  - (e) Coincidences.
- (20) Conditions of—
  - (a) Scientific discovery.
  - (b) Determination of the nature of a discovery contrasted with barren reasoning.
- (21) Dependence of discovery upon art of exceptional instances.
- (22) Fundamental laws of discovery.

The word "discovery" naturally suggests "What led Columbus to discover America?" His deductive capacity must have been very great, and no doubt mentally he must have gone through more than one of those phases

described in the tabular statement arranged by Gore. The expedition of Columbus was no happy-go-lucky one, but made with a definite purpose founded on certain definite facts known beforehand. It is interesting to remember that while on his voyage of discovery and founding another continent, Columbus discovered many curious facts with regard to compass variation.

In concluding these remarks the writer of this essay hopes that at any rate some of the ideas and suggestions put forward may lead to a better understanding of what is in these modern times required to be borne in mind in the training of those who are going to be our captains of industry, also of the channels through which discovery and invention are likely to be brought about.

## The Nitrate Situation

### Report of Committee on Public Relations of American Electrochemical Society

The Committee on Public Relations of the American Electrochemical Society has sent the following recommendations to the President, the Secretary of the Navy, and the Secretary of War:

Inasmuch as the utilization of atmospheric or other sources of nitrogen to supplant Chilean nitrate in this country for the manufacture of explosives and as a source of fixed nitrogen for fertilizers is in many respects an electrochemical problem, the undersigned members of the Committee on Public Relations of the American Electrochemical Society, constituted of the president and past-presidents of the society, feel justified in making the following statements and recommendations:

1. We urge upon this government the necessity of providing at once eighteen months' supply, on a war basis, of Chilean nitrate, using government ships if necessary, this reserve to be stored at various strategic points.

2. Almost all of those who have intimate knowledge of the practical working of nitrogen processes are in one way or another associated with some particular process, and we know of no experts who could be considered as having a strictly unbiased mind on the subject, as the government should be in possession of accurate confidential information regarding present developments in each of the processes proposed to date in order to be able to act wisely and promptly in case of sudden emergency, we add our indorsement to the recommendation already made by the Naval Consulting Board and others, that a small committee of appointees by the President be delegated to visit each of these groups of men who control these processes and who have already intimated their willingness to furnish proper representatives of the government with full confidential data.

3. As we confidently hope that this country may never be involved in war, while thoroughly believing it should be prepared for immediate defense, it should be remembered that the great peace use of fixed nitrogen is as a plant food, and it is therefore desirable that private interests be allowed to develop the best and cheapest process on a peace basis without either government aid or government hindrance unless equally applied to all comers. We are therefore opposed to a government subsidy to any particular process at the present time, or the immediate construction of a government plant working any particular process. All of the processes can apparently be greatly improved, and the evolution of the best process will proceed more rapidly than under the artificial stimulation which government backing would give to any single process. The purchase of a suitable supply of Chilean nitrate and the possession of information upon which to base an emergency decision



advocated above will serve the purpose of military expediency without discouraging private initiative. We are, however, in favor of a liberal water power policy, as the question of the cost of power is vital to several of the processes. We believe it is in the highest degree conserving resources to make use of the otherwise wasting water power which can be conserved in no other way, and thereby preserving other sources of power, as coal, gas and oil.

4. The processes to be considered may be classified into those which produce nitric acid by direct union of the nitrogen and oxygen of the air, such as the Birke-land-Eyde and the Pauling processes; those which produce ammonia by direct union of nitrogen and hydrogen, such as the Haber process; those which fix nitrogen in a complex compound, such as the cyanamid process, and the action of nitrogen fixing bacteria in natural fertilization, and, finally, natural sources of fixed nitrogen, the only one which is of sufficient magnitude to warrant consideration is by-product ammonia derived from the distillation of coal. All of these, except the arc processes, produce ammonia, and as this and not nitric acid is the chief desideratum for fertilizer purposes, there is not sufficient commercial incentive for the carrying of these ammonias of varying degree of purity through the nitric acid required in the manufacture of explosives. All of the processes except that involving the use of bacteria have more or less active exponents in this country. We therefore urge that the research facilities of the government be concentrated upon these two points: The oxidation of ammonia and the modus operandi of nitrogen-fixing bacteria. This could be done with the aid of some of the government departments. Thus the Bureau of Mines should be able to investigate the oxidation of ammonia while the fixation of nitrogen by bacteria might be well studied by the Bureau of Soils.

#### COMMITTEE ON PUBLIC RELATIONS,

FRANCIS A. J. FITZGERALD,  
E. G. ACHESON,  
LAWRENCE ADDICKS,  
L. H. BAEKELAND,  
W. D. BANCROFT,  
CHARLES F. BURGESS,  
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CARL HERING,  
F. A. LIDBURY,  
WILLIAM H. WALKER,  
W. R. WHITNEY.

## The Western Metallurgical Field

### Geological Survey's Mid-Year Review

Following a practice begun last year, the U. S. Geological Survey has issued a mid-year review of the mineral industry, showing the remarkable accomplishment of the first six months of 1916. From these indications the forecast is made that 1916 will be a record-breaking year. Coal, iron and steel, cement and oil have experienced unusual demands, and large gains over last year's records are easily foreseen.

Most precious-metal mines are operating at full capacity. The gold production will probably fall below the high yield of last year, but silver, the one metal last to benefit by the general domestic prosperity, is expected this year to break all previous records.

In Colorado the gold production of Cripple Creek, which accounts for 60 per cent of the State's output, has fallen off appreciably, and the San Juan region has not maintained its output of 1915. From California it is reported that the U. S. Mint and local smelters and refiners are in receipt of \$366,000 less gold and 22,000

more ounces of silver during the first five months of 1916 than in the corresponding period a year ago. Nevada also will likely show a decrease in gold, due to declining production at Goldfield and the failure to discover new important deposits. Bullion receipts from Oregon mines show an increase in both gold and silver, the former being due entirely to dredging operations.

Copper is continuing the steady increase in production which began early last year, and the forecast for 1916 indicates not only the largest output ever known but also the largest profits. In Nevada the copper output has been increased more than 50 per cent, and the value at present prices will be double that of last year. Arizona will continue to hold first place among copper-producing States, producing 600,000,000 lb. of copper if production continues at present rate, which is nearly double that of any other State. In Utah the probability is that the year's production of copper will be 225,000,000 lb. The value of copper produced will be about double that of 1915.

The lead and zinc mines are producing ore at a rate even exceeding that of last year, and the prevailing prices have made possible the working of large quantities of low-grade ore. From Idaho shipments of lead are being made at the rate of 360,000,000 lb. per annum, and there will be a corresponding increase in the output of silver. Coeur d'Alene companies are shipping lead concentrates and ore at the rate of over 30,000 tons a month, and zinc material at the rate of over 8000 tons a month. No great increase in zinc is looked for in Utah, but Colorado is expected to exceed the record of 1915.

In quicksilver the outlook is for a continuance of the output of 1915, which was the largest for several years. Thus far in 1916 the average price has greatly exceeded the 1915 prices; and although the reaction in prices has come, conditions are favorable for steady and profitable operation of the quicksilver mines, some of which are newly opened.

Shipments of iron ore from Lake Superior points for five months of 1916 exceeded by more than 80 per cent those for the same months in 1915, and the indications for the year are favorable for a new high record on iron-ore production, and of pig iron as well. Higher prices with a steady demand are stimulating the mining of manganese, with the result that this year's output of ore is expected to surpass the large production of last year.

### Electrolytic Zinc in Utah

Construction of the new electrolytic zinc plant for the Judge Mining & Smelting Co., at Park City, Utah, is progressing satisfactorily, the excavation and foundations having been completed. The work is being pushed with vigor in order that production may begin at an early date. When the new plant is completed it will handle about thirty tons of high-grade zinc concentrates per day and turn out about fifteen tons of electrolytic zinc. It is reported that a feature of the electrolytic work will be the use of revolving cathodes of aluminium. While other experimental work has been done on electrolytic zinc in Utah, the Judge plant will be the first to operate on a commercial scale.

### Production of Platinum in California and Oregon

An increase in the production of crude platinum in California and Oregon in 1915 is reported by the U. S. Geological Survey. The official figures show an output of 741.91 troy ounces, valued at \$23,538. This is an increase of 171.91 ounces over the production in 1914. California is the principal producer, only one mine in Oregon reporting any output. Platinum refiners report that a total of 8665 troy ounces of new



metals of the platinum group was recovered, of which at least 1587 troy ounces is believed to be of domestic origin.

Secondary metals derived from the refining of scrap and sweeps to the amount of 42,970 troy ounces were sold in 1915.

Notwithstanding the embargo placed upon the exportation of platinum by all the allied governments, the United States imports of platinum and allied metals during the year 1915, as compiled by the Bureau of Foreign and Domestic Commerce, Department of Commerce, were only 10 per cent below the 1914 imports, amounting in all to over 69,000 ounces, having a value of \$2,768,688.

Figures showing the world's production of platinum and allied metals are at best estimates made from the most reliable information obtainable. The table below gives the best estimates from information available to the Geological Survey at this time:

Country	1912	1913	1914	1915
Borneo and Sumatra .....	200	200	(*)	(*)
Canada .....	30	50	30	100
Colombia .....	12,000	15,000	17,500	19,000
New South Wales .....	778	1,275	1,248	556
Russia .....	300,000	250,000	241,200	124,000
United States .....	721	483	570	742
	313,729	267,008	260,548	143,898

\* No basis for estimate.

† No figures from Tasmania available at time report goes to press.

#### Teck Hughes Cyanide Mill, Ontario

The Teck Hughes property in the Kirkland Lake district of Ontario is equipped with a 50-ton cyanide mill of the continuous decantation type. Primary crushing is done with a 16 in. by 10 in. jaw breaker of the Blake type, and subsequent grinding by a 5 ft. by 5 ft. ball mill. The ball-mill discharge is further ground in a 5 ft. by 20 ft. tube-mill running in closed circuit with a Dorr classifier. The slime thus produced is treated by continuous agitation and decantation in Dorr agitators and thickeners. A change of solution is made after agitation is two-thirds complete, in accordance with practice which has been explained at length in former articles in this journal. The thickeners are of the tray type which have been proving popular in recent installations. Due to the high grade of the ore and relatively high strength of cyanide solutions, a filter of the Oliver type follows the decantation system as is customary under such conditions.

#### Some Unusual Conditions in Oklahoma Zinc Mines

An occurrence of hydrogen sulphide in the new zinc mines of the Picher Company at Picher, Okla., constitute an unusual phenomenon that has caused some trouble in mining operations. The characteristic odor of the gas is plainly perceptible about the shafts and in the workings, and water pumped from the mines is milky with precipitated sulphur. The effect on the workmen is such that they are unable to put in a full shift without relief. Practically all the miners become affected with what is locally known as "pink eye," an affection of the membranes of the eye that causes inflammation and discomfort. In some cases the affection is so acute that the men can work only during alternate two-hour periods. Various remedies have been used, but one of the best that had been tried was the wearing of goggles that keep the gases from the eyes. The workings are ventilated by blowers and exhaust fans, the former at the shafts and the latter at drill holes connecting with the drifts. As far as is known the occurrence is localized at the properties mentioned.

Another unusual condition is encountered at the property of the Admiralty Company near Cardin. Here the ore is impregnated with a natural hydrocarbon that gives considerable trouble in milling. The ore is black in appearance and has a strong odor of mineral oil. The concentrates also have an oily appearance and odor. The chief difficulty encountered in milling was due to the clogging of the jig screens by the hydrocarbon material. This has been overcome by introducing kerosene under the screen of the first compartment of the jig, thus "cutting" the heavy oil and keeping the screens clear. Several barrels of kerosene are used per day, fed under pressure from a reservoir in the hoist house. Other oils were tried, such as gasoline, but kerosene proved most effective.

#### Production of Gold and Silver in the United States

The Bureau of the Mint and the Geological Survey have issued the following joint statement as to the final figures on the production of gold and silver in the United States during the calendar year 1915:

State or Territory	GOLD		SILVER	
	Fine Ounces	Value	Fine Ounces	Value <sup>1</sup>
Alabama .....	247	\$5,100	.....	.....
Alaska .....	808,346	16,710,000	1,054,634	\$526,100
Arizona .....	220,392	4,555,900	5,665,672	2,826,500
California .....	1,090,731	22,547,400	1,889,924	843,100
Colorado .....	1,089,928	22,530,800	7,199,745	3,591,900
Georgia .....	1,684	34,800	141	100
Idaho .....	56,628	1,170,600	13,042,466	6,506,800
Illinois .....	.....	.....	3,892	1,900
Michigan .....	.....	.....	581,874	290,300
Montana .....	240,825	4,978,300	14,423,173	7,195,600
Missouri .....	.....	.....	55,534	27,700
Nevada .....	574,874	11,883,700	14,453,085	7,210,500
New Mexico .....	70,632	1,460,100	2,337,064	1,165,900
North Carolina .....	8,258	170,700	1,496	700
Oregon .....	90,321	1,867,100	125,499	62,600
Philippine Islands .....	63,898	1,320,900	15,148	7,600
Porto Rico .....	34	700	.....	.....
South Carolina .....	174	3,600	.....	.....
South Dakota .....	358,145	7,403,500	197,569	98,600
Tennessee .....	329	6,800	99,171	49,500
Texas .....	87	1,800	724,580	361,500
Utah .....	189,045	3,907,900	13,073,471	6,522,200
Vermont .....	.....	.....	150	100
Virginia .....	24	500	.....	.....
Washington .....	22,330	461,600	213,877	106,700
Wyoming .....	672	13,900	2,910	1,400
Total .....	4,887,004	\$101,035,700	74,961,075	\$37,397,300

<sup>1</sup> At the average price of silver per fine ounce for the calendar year 1915, \$0.49889.

These figures compare with the production of 1914—\$94,531,800 in gold and 72,455,100 fine ounces of silver, being a gain in the gold production of \$6,503,900 and 2,505,975 fine ounces in the silver product.

#### Company Reports

Alaska Gold Mines Co. made a profit of \$251,848 in 1915, being 22.581 cents per ton treated. Miscellaneous income of \$26,923 is to be added. The first section of the mill began operations on February 12, 1915, and the full average tonnage of 6000 tons per day was maintained by November. Steps were taken to increase the capacity to 12,000 tons per day. During the year 1,115,294 tons of ore was milled, having an average value of \$1.1569 per ton. Average tailings were 21.91 cents, showing an extraction of 81.06 per cent. Average total milling cost for the year was 30.496 cents, though in November the cost was but 25.699 cents. Average total net cost for the year in mining, milling and disposition of products, inclusive of all fixed and general charges was 69.039 cents per ton. The same cost in November was 59.785 cents.

Butte & Superior Copper Co. had an operating profit in 1915 of \$9,074,151, with miscellaneous income of \$51,795, making a total of \$9,125,946, as compared with \$1,417,127 in 1914. Dividends paid amounted to \$4,908,115. Under the company's contract with the American Zinc, Lead and Smelting Co., the spelter

produced from Butte & Superior Concentrates is returned to the original company for sale in open market. Owing to the fact that the word "Copper" in the company's name is misleading, and inasmuch as the chief product is zinc it is proposed to change the name of the concern to Butte & Superior Mining Co. Developed ore reserves at the end of the year were about the same as a year previous, and amounted to about 1,000,000 tons. Total ore mined amounts to 522,949 tons at an average cost of \$3.36 per ton. The flotation plant was rebuilt for the purpose of increasing capacity and increasing efficiency. An increase in capacity 60 per cent greater than in 1914 was brought about without extensive additions to plant. Total ore milled amounted to 522,300 tons, but late in the year the average was 50,000 tons per month or at the rate of 600,000 tons per year. Average zinc content of ore milled was 17.02 per cent; of silver, 7.63 ounces per ton. Mill recovery averaged 92.21 per cent, but for the last quarter it was 95.07 per cent. Average cost of milling was \$1.75 per ton, as compared with \$2.12 for 1914.

### The Iron and Steel Market

The steel market has turned distinctly stronger in the first half of August, a reflection in part of the remarkable stability it showed during June and July when in the face of very light demand prices were held very firmly and the mills appeared to be quite indifferent as to whether or not they booked additional business, and a reflection also of the heavier demand for shell steel than had been expected.

The new development of August is that resistance to weakness has given way to a positive exhibition of strength. The new movement started with the official announcement on the afternoon of August 1 that the Carnegie Steel Company had advanced its price on merchant steel bars \$2 a ton, from 2.50c. to 2.60c. The independents began quoting the advanced price in a limited way, while they closed at 2.50c. such pending negotiations as could be brought to a head, and the market is now practically established on the higher basis. Structural shapes showed a tendency to move up in harmony with bars even though on account of the peculiar alignment of demand for different products at this time the demand for shapes is relatively light while the relative demand for bars is abnormally heavy. Plates are now predicted for a rise also, and wire products are moving upwards.

Buying of steel in the domestic market goes by movements and a movement must have an exciting cause, such as price advances or mills falling farther behind in deliveries. The last buying movement began to wane in March and came to an end in May, since which time the buying has been spasmodic and sporadic in character. At the beginning of June the balance of probability seemed to be that there would not be another buying movement until there had been a readjustment in prices, and in some quarters it was thought far from improbable that the market would weaken toward the close of August or in September, not because the large mills would not get additional business but because the small mills presumably would, since customarily they do not sell far ahead. The small mills are now found to be in strong position, however. As time has passed predictions have begun to appear that a fresh buying movement of some proportions would start in the fall, presumably in September, and the events of the past fortnight have tended to strengthen the expectation.

### Export and War Demand

A strong factor in the further stiffening in the steel situation has been the unexpectedly heavy demand for

steel for export and for shell manufacture. There was heavy buying of shell steel in April and May and at the close of May it was rather thought that substantially all the business for the second half of this year had been placed. The buying has, however, continued on a large scale. In the past thirty days it appears that more than half a million tons of shell steel has been placed, with negotiations for a considerable tonnage still pending. The recent business involves a larger percentage of shell steel to be shipped abroad in the form of rolled rounds and forging billets, as the capacity for making shells abroad, particularly the smaller shells, has been rapidly increasing. There is a large decrease in the manufacture of small shells in the United States, but the manufacture of large shells is increasing, and on the whole it would appear that the production of shell steel is increasing, though possibly a somewhat smaller tonnage will be converted into shells in this country.

Apart from this movement in shell steel there is continued heavy demand for soft steel for export, apparently because the steel works abroad are diverting more of their capacity to the manufacture of shell quality, involving a greater call upon the United States for soft unfinished steel. As a result of these conditions the market for soft steel billets and sheet bars is a trifle stronger than at any previous time in this movement.

### Production Decreased

Since the first of July the production of pig iron has been at a rate of about 38,250,000 tons a year, contrasting with the high rate of 39,800,000 tons attained in May. The chief factor in reducing the output has been the extremely high humidity, much above the normal even for July and August. A smaller but hardly a negligible factor has been the necessity of blowing out quite a number of furnaces for relining, more furnaces having gone out since July 1 than have gone in. It is quite evident that the furnace performance last spring was abnormally good and it seems certain that the existing furnaces cannot for a twelvemonth maintain an average rate of 40,000,000 tons. The maximum rate attained before this movement was 34,000,000 tons, in March and April, 1913, and not more than half the increase in the rate to last May can be attributed to the completion of new furnaces. Scarcely any new stacks will come in during the balance of this year and while about twenty-five new furnaces are being built it seems improbable that all will be completed by the end of 1917.

The very hot weather has decreased steel mill operations more than pig iron output, the production of finished steel being reduced, from the June rate, by more than 10 per cent, and thus pig iron has not grown scarcer, though it may do so later in the year.

### Pig Iron

Pig iron has been stagnant in all districts, buyers apparently being well covered. Occasionally interest is manifested in foundry iron for the first quarter or first half of 1917 but the furnaces are indisposed to quote, feeling that the balance of probability is that prices will be higher later in the year. In some quarters a buying movement is predicted for September, chiefly on the ground that as steel making capacity is being increased by various additions there will be more iron needed than has already been provided. Some of the large steel interests, normally self-contained, may enter the market.

### Steel

Soft steel is strong at a general level of about \$45 for either billets or sheet bars. While Bessemer may be



a shade lower than open-hearth there seems to be little distinction at this time. Rods are \$55 to \$60, with high carbon rods commanding unusual premiums over mild steel grade.

#### Production of Tin Plate and Galvanized Sheets

Statistics have just been made public showing the production in 1915 of tin plates, terne plates and galvanized sheet products, the comparison being as follows, in gross tons:

	Tin Plate	Terne Plate	Total Tin and Terne	Galvanized Sheets	Galvanized Formed Products
1913	762,553	61,136	823,719	824,047	57,674
1914	865,975	65,266	931,241	806,994	58,752
1915	982,958	72,978	1,055,936	706,058	50,119

The previous record year for tin and terne plate production was 1912, with 962,971 tons. The decrease in galvanized sheet production in 1915 is less than would have been predicted as the high-priced spelter reached before the middle of the year eventually caused a large decrease in galvanizing operations. The mills evidently operated on relatively cheap spelter for a while after the top was reached in the spelter market in June.

#### The Non-Ferrous Metal Market

**Copper.**—There has been little doing in the past two weeks in copper. The market remains firm, however, as it is pretty well sold up. Electrolytic was quoted on Aug. 11, at 26.50c. for spot and August deliveries, New York, with futures at 26c. Lake is quoted at 26.75c. spot.

**Tin.**—This market has been generally quiet. There is a large supply of Banca tin on hand which was quoted on Aug. 11, at 36.25c. New York, when Straits was held at 37.67½c. for spot. Deliveries to consumers in July amounted to 4432 tons.

**Lead.**—On Aug. 2 the American Smelting & Refining Company reduced its price from 6.50c. to 6 cents New York, a reduction which was generally expected, and which was thought would bring large business. The reduction did not stimulate buying to any great extent, however. Independents are asking 5.95c. New York.

**Spelter.**—This metal is dull and weak with little business done. Spot spelter was quoted on Aug. 11 at 8.50c. New York, while 7.75c. was asked for November and December delivery.

**Other Metals.**—*Antimony* continues downward and 11c. is quoted for Japanese and Chinese. *Aluminium* is quoted at 58c. to 60c. for No. 1 virgin metal. *Platinum* is quoted at \$60 per ounce; *Magnesium* at \$3.50 per pound; *Quicksilver* at \$75.00 per flask, with silver at 66¼c.

#### Coming Meetings and Events

American Institute of Metals and American Foundrymen's Association, Foundrymen's Convention, Cleveland, Sept. 11-16.

American Institute of Mining Engineers, Arizona, Sept. 18-23.

Mining and Metallurgical Society of America, New York Section, New York, Sept. 21.

Second National Exposition of Chemical Industries, New York, Sept. 25-30.

American Chemical Society, New York, Sept. 25-30.

American Electrochemical Society, New York, Sept. 28-30.

Technical Section, American Paper and Pulp Association, New York, Sept. 25-30.

American Institute of Chemical Engineers, New York, Jan. 10-13, 1917.

#### Technical Societies and the Second National Exposition of Chemical Industries

The society meetings and the Second National Exposition of Chemical Industries which are to be held in conjunction with each other in New York from Sept. 25 to 30, provide a week of great interest and value to the chemical industries and to all those interested in chemistry. It is a combination which no one so interested can afford to miss.

The American Electrochemical Society has planned a series of very interesting sessions for its thirtieth general meeting, which will be held during the week of the show on Sept. 28, 29 and 30. The meeting will be opened on Thursday with the "Made in America" technical session devoted to a review of American progress in the electrochemical industry. A complimentary smoker will be held on Thursday evening to which members of the American Chemical Society, and other visiting engineers are invited, and on Friday evening there will be a joint banquet at the Waldorf-Astoria of the members of the American Chemical Society, The American Electrochemical Society, and the Technical Association of the Pulp and Paper Industry. This will be a subscription banquet and the price of tickets to members will be \$3.50; additional tickets for guests will be obtainable at cost, or about \$7.

The first general session of the American Chemical Society will open at Columbia University on Tuesday morning, Sept. 26, and arrangements are being perfected for a public meeting in the large hall of the College of the City of New York on Tuesday afternoon, when addresses will be made of general public interest pertaining to the interesting developments in the field of applied chemistry during recent years. More detailed announcements will be given in a later issue.

Dr. Charles H. Herty, of the University of North Carolina, president of the American Chemical Society, will open the exposition on Monday, Sept. 25, at 2 o'clock in the afternoon, with an address reviewing the history of chemistry and the chemical industries in this country and outlining developments since the outbreak of war in Europe.

On Aug. 1, 1915, there were thirty-seven pledged exhibitors to the First National Exposition of Chemical Industries. On Sept. 20, 1915 the Exposition opened with eighty-three exhibitors.

On Aug. 1, 1916, there are 125 pledged exhibitors to the Second National Exposition of Chemical Industries—an increase of nearly 350 per cent. By Sept. 25 of this year the management expects to have the third floor of the Grand Central Palace filled. Out of the eighty-three exhibitors of last year all but four will exhibit again this year. Last year there were 63,377 admissions to the Exposition—this year it is not unreasonable to expect an attendance of 100,000.

Appliances and equipments used in the whole range of American chemical industry will be shown.

While it is utterly impossible to show large processes in actual operation yet the equipments used will be on exhibition and there will be men present, expert in their various lines to explain. One great section of the Exposition will be devoted to the paper industry. The dye-stuff industry will be extensively represented. There will be shown what has been accomplished in America in the production of potash. An interesting feature will be a demonstration of the ultra-microscope. The great natural resources of the United States and Canada will be vividly shown. Many chemical processes, that could not be demonstrated in actual operation in such a building as the Exposition will be shown in motion pictures.



## The Working Efficiency of Rolling Steel

BY SIDNEY CORNELL

Descriptive matter in relation to the blast furnace, the open-hearth, and the rolling mill is abundant in technical magazines, but the human side of the art is rarely touched upon by any writer, either in America or in Europe. Technical men have given us many valuable articles from a purely scientific standpoint, and one author states that metallurgical progress in connection with the blast furnace has not been what it should have been, due to the fact that the authors of articles are inclined to write lop-sided heat balances rather than devote their time to mechanical problems.

This may be true, but all progress costs money, and the money seldom comes from the man who operates the various metallurgical apparatus, single units of which may cost as much as \$1,000,000 to build and \$2,500,000 per year to operate. Another and deeper side of the problem, therefore, presents itself, the basis of which is accounting.

The accounting of the steel works industry has not yet been approached in such a detailed way as to make it truly scientific, I may safely state that steel works accounting is usually a most lop-sided affair of lumped expenditure and lumped returns, yielding a fair profit or otherwise, but usually the former.

Efficiency involves detail, and the attendance to detail will reward its followers sooner or later. In this article I will present not a series of accounting methods, but a compilation of observations involving details, each detail in turn often involving further details, but leading up to the unknown quantity of what it really costs to make steel.

In many ways the steel industry practices material efficiency of a high order. Metal is produced in a fair degree of efficiency as far as yield is concerned and it is possible to follow the process visually in the transformation of iron ore to finished steel article. In this transformation the money expended can reach surprising figures, and the steel works early became efficient in the utilization of all scrap material. However, they have never known what the value of that scrap material was, and have apparently never cared. In the following I wish to present observations which will bring out in a simple manner the real cost of making steel.

My figures are taken from many sources, but I am confining the discussion to a steel plant containing blast furnaces, open-hearth furnaces, bloomers, billet mills, and merchant mills, and all of the auxiliaries needed in such a plant. Some of the cost units used would be higher and others would be lower for other localities, and for any specific case these changes would have to be duly considered, but the working of the method is plainly evident. A plant located some twelve miles from Pittsburgh is taken as representative.

The plant covers 150 acres of land, and includes six blast furnaces, thirty-two open-hearth furnaces, a 38-in. and a 40-in. blooming mill, a rail mill used to roll light shapes, billets, and sheet bar, and continuous mills, arranged so that the product of the 38-in. mill passes through the rail mill and continuous mill and so that the product of the 40-in. mill may be passed through another continuous mill. Secondary to these are five merchant bar mills, namely a 22-in., a 13-in., two 10-in. mills and an 8-in. mill. For convenience the above mills are here called 1A Bloomer (38 in.); 2A Bloomer (40 in.); 1B rail mill; 1C the one 14-in. continuous mill; 2B the other 14-in. continuous mill. The merchant mills are called 1M (10 in.), 2M (13-in.), 3M (8 in.), 4M (10 in.), and 5M (22 in.). The value of such a plant, bought

piecemeal, and involving great improvements from time to time with the writing off of values, makes the subject of overhead a difficult one and the only way to arrive at any figures worth considering is to give present working values comparatively.

The product of such a plant for an average month is tabulated in Table I.

TABLE I—DISTRIBUTION OF STEEL AND IRON IN THE VARIOUS DEPARTMENTS FOR AVERAGE MONTH

Part of Mill	TOTAL CHARGED		PRODUCT		SCRAP METALLIC		LOSS, ROLL SCALE, ETC.	
	Am't Tons	Per Cent	Am't Tons	Per Cent	Am't Tons	Per Cent	Am't Tons	Per Cent
Blast furnaces.....	.....	.....	80,100	...	.....	.....	.....	...
Pig to O. H.....	.....	.....	64,500	...	.....	.....	.....	...
Pig sold.....	.....	.....	15,600	...	.....	.....	.....	...
Open hearth.....	116,000	100.00	103,200	88.96	6,000	5.17	6,800	5.87
Castings.....	.....	.....	300	...	.....	.....	.....	...
Steel to mills.....	.....	.....	102,900	...	.....	.....	.....	...
1A Mill.....	66,000	100.00	56,800	86.06	8,000	12.12	1,200	1.82
1B Mill.....	56,800	100.00	54,000	95.07	2,500	4.40	300	.53
1C Mill.....	14,100	100.00	13,000	92.20	1,000	7.09	100	.71
2A Mill.....	36,900	100.00	29,200	79.13	7,100	19.24	600	1.63
2B Mill.....	10,500	100.00	9,700	92.38	750	7.14	50	.47
1 M. Mill, 10 in.....	8,000	100.00	7,200	90.00	650	8.12	150	1.88
2 M. Mill, 13-in.....	9,000	100.00	8,000	88.88	900	10.00	100	1.12
3 M. Mill, 8-in.....	1,550	100.00	1,400	90.32	125	8.06	25	1.62
4 M. Mill, 10-in.....	2,800	100.00	2,500	89.28	250	8.93	50	1.79
5 M. Mill, 22-in.....	8,500	100.00	7,400	87.06	1,000	11.76	100	1.18
Special product of Merchant Mill	2,200	100.00	2,150	97.72	50	2.28	.....	.....

The material efficiency of the various mills is shown in the column per cent under product. The net efficiency from a material standpoint is derived as follows:

The 102,900 tons of steel delivered to the mills are first rolled in mills 1A and 2A. Sixty-six thousand tons rolled in 1A, give 56,800 tons of product, which is rerolled in 1B mill, yielding in turn 54,000 tons of product, and from this 14,100 tons are rolled in 1C mill, giving 13,000 tons of product, so that out of the 66,000 tons rolled on in 1A mill, the product is  $39,900 + 13,000 = 52,900$  tons.

The 2A mill rolls on 36,900 tons giving 29,200 tons from which 10,500 tons are rolled on in 2B mill, so that the net product from this side is  $18,700 + 9,700 = 28,400$  tons.

The total product of mills 1A and 2A is thus  $52,900 + 28,400 = 81,300$  tons, in the form of blooms, billets, sheet bar and light shapes. From these 81,300 tons there must be taken 29,850 tons of blooms and billets for mills 1M to 5M, leaving 51,450 tons for sale. These 29,850 tons give 26,500 tons of product. From this product 2200 tons are used to furnish 2150 tons of finished specialty, while the remaining 24,300 tons are saleable in the form of merchant bar.

The saleable product of the above steel plant is thus:

	Tons
Pig iron.....	15,600
Blooms, billets, sheet bar.....	51,450
Merchant bar.....	24,300
Special merchant bar product.....	2,150
Castings.....	300

or 15,600 tons of pig iron, and 78,200 tons of finished and semi-finished steel. As 116,000 tons of metal were charged to the open hearth and 78,200 tons of product were finally obtained, the material efficiency of the conversion is 67.4 per cent. During this conversion a total of 28,325 tons of metallic scrap is produced, together with 9475 tons of roll scale, cinder, etc., all of which must be remelted in the open hearth or blast furnace. It is quite obvious that the cost of this scrap and scale is not what the market value would be, and it is upon this point that the following tabulations rest.

In order to arrive at a basis for figuring the real

efficiency of a steel plant it is first necessary to consider all of the non-producing departments connected therewith and accordingly I am tabulating these departments as follows, using a decimal system of numbering.

The non-producing departments are a matter of simple accounting and each producing department bears the burden in exact proportion to the service rendered.

#### Account 1—Steam.

- " 2—Water.
- " 3—Electrical.
- " 4—Transportation.
- " 5—Maintenance shops.
- " 6—Roll shop.
- " 7—Laboratory.
- " 8—Store rooms.
- " 9—General works.

The last item General Works is the only one that serves generally and the sum so expended must be distributed in proportion to the tonnage of the various producing departments.

The above nine accounts are dealt with in Tables II to X.

The average conditions for the production and utilization of steam for an average month's account is as follows, steam costing \$2.60 per boiler horsepower, month.

TABLE II—STEAM. ACCOUNT 1

Part of Mill	B.H.P.	Cost
Blast furnaces, steam consumed	8,000	\$20,400.00
Steam sent to steel works from B. F.	9,100	
Steam generated in steel works	4,670	
Total steam used in upper works	13,770	\$35,800.00
Water, Steam used	660	1,720.00
Electrical power	2,175	5,650.00
Open hearth	685	1,775.00
1A mill	2,500	6,500.00
1B mill	3,450	8,970.00
1C mill	1,400	3,640.00
2A mill	2,600	6,760.00
2B mill	300	780.00
Total	13,770	\$35,800.00
1M mill	745	1,940.00
2M mill	600	1,560.00
3M mill	385	1,000.00
4M mill	415	1,080.00
5M mill	1,475	3,840.00
Special product	100	260.00
Total	3,720	\$9,880.00
Boiler horsepower. Coal fired	8,390	
Boiler horsepower. Gas fired	17,100	
Total	25,490	
Coal used = 10,500 tons		
Water used = 64,100,000 gallons		

Average conditions for water for average month with distribution in 1000 gal., and at a cost of \$0.004 per 1000 gal. pumped is given in Table III. Water for boilers excluded as cost appears in steam.

TABLE III—WATER. ACCOUNT 2

	1,000 Gallons	Cost
Blast furnaces	1,280,000	\$5,120.00
Open hearth	175,000	700.00
1A mill	30,000	120.00
1B mill	50,000	200.00
1C mill	25,000	100.00
2A mill	40,000	160.00
2B mill	25,000	100.00
1M mill	20,000	80.00
2M mill	20,000	80.00
3M mill	10,000	40.00
4M mill	10,000	40.00
5M mill	30,000	120.00
Total	1,715,000	\$6,800.00

Average conditions for average month, distributed in kilowatt-hours, at a cost of \$0.005 per kilowatt-hour.

TABLE IV—ELECTRICAL POWER. ACCOUNT 3

	Kilowatt-Hours	Cost
Water	145,000	\$725.00
Blast furnaces	350,000	1,750.00
Open hearth	275,000	1,375.00
1A mill	100,000	500.00
1B mill	65,000	325.00
1C mill	15,000	75.00
2A mill	45,000	225.00
2B mill	15,000	75.00
1M mill	100,000	500.00
2M mill	100,000	500.00
3M mill	40,000	200.00
4M mill	60,000	300.00
5M mill	200,000	1,000.00
Shops	50,000	250.00
Total	1,560,000	\$7,800.00

TABLE V—TRANSPORTATION. ACCOUNT 4

Blast furnaces	\$10,000.00
Open hearth	5,000.00
1A mill	None
1B mill	1,100.00
1C mill	500.00
2A mill	600.00
2B mill	500.00
1M mill	300.00
2M mill	300.00
3M mill	200.00
4M mill	200.00
5M mill	400.00
Spec. product	200.00
Total	\$19,300.00

TABLE VI—MAINTENANCE SHOPS, ACCOUNTS

	Machine Shop	Blacksmith Shop	Boiler Shop	Pipe Shop	Carpenter Shop	Millwright Shop	Brick Layers	Electricians	Painters	General Labor	Total
General works	...	50	15	200	20	120	50	40	50	545	
Steam	175	10	700	450	90	30	400	20	25	550	2,430
Water	700	10	20	500	100	150	100	15	250	1,845	
Electricity	10	10	10	50	10	675	10	75	640		
Transportation	1,650	250	375	75	150	80	50	1,500	4,100		
Laboratory	50	10	10							80	
Blast furnaces	3,300	440	1,050	585	645	170	790	825	60	8,250	11,215
Open hearth	1,250	515	665	160	845	65	2,940	1,125	20	1,700	9,985
1A Mill	950	420	260	115	265	100	1,225	315	10	1,500	3,810
1B Mill	700	280	175	80	175	80	750	210	10	1,250	2,585
1C Mill	250	145	90	35	90	40	475	105	5	1,000	1,335
2A Mill	500	245	200	120	170	85	450	260	5	1,500	2,185
2B Mill	150	65	30	30	35	75	140	30	5	600	690
1 M. Mill, 10-in.	160	25	65	40	40	10	35	125	5	150	655
2 M. Mill, 13-in.	185	45	100	50	30	10	35	110	5	200	770
3 M. Mill, 8-in.	30	5	25	5	15	5	25	10		50	170
4 M. Mill, 10-in.	40	5	30	5	15	5	25	10		50	185
5 M. Mill, 22-in.	150	65	65	40	40	10	90	155	10	200	825
Total, dollars	10,240	2,545	3,920	2,315	2,955	905	7,620	4,000	260	11,650	46,449

TABLE VII—ROLL SHOP, AVERAGE CONDITIONS FOR AVERAGE MONTH. LABOR AND MATERIAL. ACCOUNT 6

1A mill	\$1,200.00
1B mill	3,500.00
1C mill	1,300.00
2A mill	1,000.00
2B mill	750.00
1M mill	300.00
2M mill	600.00
3M mill	300.00
4M mill	300.00
5M mill	1,500.00
Total	\$10,750.00

Laboratory account includes physical inspection as well as chemical control. Rejections to the amount of about 3.0 per cent of the product (which goes into scrap) are made through the laboratories.

TABLE VIII—LABORATORY. ACCOUNT 8

Blast furnaces	\$2,000.00
Open hearth	1,400.00
Soaking pits	35.00
1A mill	50.00
1B mill	25.00
1C mill	40.00
2A mill	25.00
2B mill	75.00
1M mill	75.00
2M mill	75.00
3M mill	75.00
4M mill	75.00
5M mill	75.00
Total	\$4,025.00



Distribution of all supplies and materials used in repairs, less any credit for salvage of material. Applies to mills only, the other stores being absorbed in the blast-furnace and open-hearth charges to follow:

TABLE IX—STORE ROOMS. ACCOUNT 8

1A mill	\$7,400.00
1B mill	2,700.00
1C mill	1,300.00
2A mill	5,850.00
2B mill	700.00
1M mill	750.00
2M mill	850.00
3M mill	400.00
4M mill	500.00
5M mill	1,250.00
	\$21,700.00

In the plant under discussion some \$28,000 per month would be expended for General Works, including the following. The taxes would amount to some \$100,000 per annum, but dependent upon local conditions, so that \$8,300 for taxes would have to be added to the monthly overhead. Itemized this would appear somewhat as follows:

TABLE X—GENERAL WORKS. ACCOUNT 9

1 Executives' salaries	\$9,500.00
2 Stationery	1,600.00
3 Postage	250.00
4 Furniture	200.00
5 Office expense	1,000.00
6 Telephone and telegraph	600.00
7 Drafting and engineering	3,000.00
8 Special departments	2,500.00
9 Watchmen and gatemen	2,500.00
1 Shop cost	545.00
2 General maintenance	3,000.00
3 Store rooms operation	1,500.00
4 Garage expense	650.00
5 Hospital and accidents	1,500.00
6 Extraordinary expenses	1,500.00
7 Taxes	8,300.00
8 Insurance	
9 Miscellaneous	
	\$36,645.00

ACCOUNT 9. DISTRIBUTION BY TONNAGE

	Per Cent	Cost
Blast furnaces	22	\$8,060.00
Open hearth	28	10,260.00
1A mill	15	5,490.00
1B mill	11	4,030.00
1C mill	4	1,465.00
2A mill	8	2,930.00
2B mill	3	1,100.00
1M mill	2	730.00
2M mill	2	740.00
3M mill	1	370.00
4M mill	1	380.00
5M mill	2	730.00
Special product	1	360.00
		\$36,645.00

From Table I we have the following scrap materials that must be disposed of and utilized as far as possible in the plant.

Metallic scrap ingot butts, etc., from open-hearth	6,000 tons
Bloom crops, and crop ends from bars, and rejected materials from the rolling mills (clean scrap)	22,325 tons
Metal loss in slags made in open-hearth	6,800 tons
Metal loss in roll scale, heating-furnace cinder in the rolling mills	2,675 tons

All of the above is not usable, due to contamination with dirty materials, brick bats, etc., but all of the clean scrap is directly usable in the open-hearth, and its recovery may be taken at 100 per cent.

In the case of open-hearth slags, they are not used in the blast furnace as ore, but are employed as a cleaning agent, to add manganese, etc., and their metallic content is thereby recovered.

Cinder and scale are used in the open-hearth replacing ore in the working of the heat, but this use is restricted to the getting of clean materials free from acid content.

In the following I have noted a reuse of 2000 tons of roll scale in the blast furnaces, and of 510 tons of roll scale in the open-hearth division, a total of 2510 tons,

having an average metallic content of 65 per cent iron. This gives a net recovery of 1631 tons of metal out of 2675 tons recorded loss, so that the material efficiency is 60 per cent.

In the recovery of metal from the slags produced in the open-hearth (where 6800 tons are so lost per month in the making of approximately 14,600 tons of open-hearth slag) only selected slag would be recharged in the blast furnaces, and the metal content of such slag would not average over 16 per cent. As 7200 tons of such slag was observed to be recharged, having a metal content of 1150 tons, and as 6800 tons were lost in the open-hearth slags, the material efficiency is about 17 per cent.

In order to arrive at the value of recovery of the waste materials, the following must be considered. The starting point is the blast furnace.

### BLAST FURNACES

The value of the raw materials used in the blast furnaces, carries us back still further, to the materials in the ground. To determine the value at the furnace the calculations of Table XI are made.

TABLE XI—NET COST OF RAW MATERIALS AT FURNACE

	Per Ton
Value of the ore in the ground unmined	\$1.200
Average cost of stripping, loading and mining	.350
Transportation to lake ports, 60 miles at \$.005 per ton-mile	.300
Lake transportation, including interest	.260
Loading and unloading steamers	.050
Transportation from lower lake ports to Pittsburgh, 120 miles at 0.005 per ton-mile	.600
Unloading and transferring to stock pile at furnace	.040
Net cost of ore on stock pile	\$2.800
Value of coking coal in the ground	\$0.60
Average cost of mining, etc.	.19
Beehive coke-oven yield = 66 per cent, or coal cost per ton coke is $(.60 + .19) \div .66$	\$1.197
Cost of coking above cost of coal	.813
Transportation from coke ovens to Pittsburgh	.710
Net cost of coke at furnace plant	\$2.72
Value of limestone (blast-furnace grade) in the ground	\$0.400
Average cost of mining and loading	.230
Transportation from quarry to Pittsburgh, 100 miles	.500
Net cost of limestone at furnace plant	\$1.030

In as much as the various materials used in the blast furnace, open-hearth, or rolling mills are all converted into materials of value or wastes, the value of flue dust, open-hearth slags, and cinder and scale are unknown at this point. A = real value of flue dust considered as a product, that is its value if iron, flue dust and slag were considered the products of a furnace, the gases being utilized entirely at the furnace plant in the production of steam.

C = real value of open-hearth slag when ingot steel, metallic scrap and all slag are considered as products.

B = real value of roll scale when considered as the product of all rollings together with the finished product.

Using these unknown values we give in Table XII the cost of iron per ton.

TABLE XII—BLAST FURNACES

Material	Tons per Month	Cost per Ton	Material Cost per Month	Cost per Ton Iron, 80100
1 Lake ores	156,700	\$2.80	\$436,800.00	\$5.452
2 Flue dust (recharged)	3,600	A	3,600.00xA	0.045xA
3 Roll scale	2,000	B	2,000.00xB	0.025xB
4 Open hearth slags	7,200	C	7,200.00xC	0.090xC
5 Coke	83,000	2.72	225,760.00	2.818
6 Limestone	36,000	1.03	37,080.00	0.463
<b>Products</b>				
1 Pig iron	80,100			
2 Flue dust	8,200			
3 Slag	48,100			

It is obvious that although the flue dust produced was charged for once as ore, that it is an accumulative material, and therefore its value of \$2.80 as ore should be deducted, the cost of flue dust recharged is the cost to make iron + flue dust + slags less \$2.80 per ton. Herein may enter a doubtful economy. In connection with flue dust it may be noted that from the 8200 tons produced there are recharged 3600 tons. This gives a material efficiency of 43 per cent for flue dust.

Writing in form of an equation the cost of materials per ton of iron, we get: Cost material per ton iron =  $\$8.733 + 0.045A + 0.025B + 0.090C$ . But to arrive at the total cost the cost above the materials must be considered. This averages as stated in Table XIII.

In order to arrive at the net cost above the materials, it is necessary to consider all credits, the laying aside of a fund for relining, and other contingent fund. A blast furnace will last approximately six years on one lining, requiring nearly \$150,000 to completely repair a furnace after making 1,000,000 tons of iron, and 15 cents a ton is taken as representative of a relining contingency and 3 cents a ton as representing general contingency.

TABLE XIII—COST ABOVE MATERIALS. BLAST FURNACE

Item	Cost Average Month	Per Ton Iron
1 Superintendents, clerks, etc.	\$2,330.00	\$0.0291
2 Ore bridges and ore pile	2,225.00	0.0277
3 Stocking and charging	9,000.00	0.1123
4 Blowing	14,000.00	0.1748
5 Hot blast	3,900.00	0.0487
6 Casting	3,500.00	0.0437
7 Material used in repairs	7,500.00	0.0936
8 Refractories used in repairs	3,800.00	0.0474
Total	\$46,255.00	\$0.5773
1 Steam. Boiler horsepower used	\$20,400.00	\$0.2547
2 Water	5,120.00	0.0639
3 Electricity	1,750.00	0.0218
4 Transportation	10,000.00	0.1248
5 Shops. Labor used for repairs	14,115.00	0.1762
7 Laboratory	2,000.00	0.0249
8 Tools and supplies	1,725.00	0.0215
9 General works	8,300.00	0.1036
Grand total	\$109,665.00	\$1.3687
1 Relining contingency fund	12,000.00	0.1500
2 General contingency fund	2,400.00	0.0300
Total	\$124,065.00	\$1.5487
Credit for steam sold	23,660.00	0.2954
Net cost above materials	\$100,405.00	\$1.2533

The products of value from the blast furnace are iron and flue dust. The latter is of value only when used as ore, and it will be noted from the tables that flue dust is produced at the rate of 8200 tons per month and reused at the rate of 3600 tons, so that this material is accumulative. There are produced in an average month 80,100 tons of iron, and of iron and flue dust and slags 136,400 tons.

Thus we have the total cost of iron per ton

$$= \$8.733 + 0.045A + 0.025B + 0.090C + \$1.2533$$

$$\text{or} = \$9.9863 + 0.045A + 0.025B + 0.090C$$

As there were made 80,100 tons of iron and a total of 136,400 tons of iron, flue dust and slags, which may be considered equally as products, and as  $80,100 \div 136,400 = 0.59$ , the value of flue dust would be  $0.59 \times$  cost of iron — \$2.80 per ton.

$$\text{Hence } A = 0.59 \times (9.9863 + 0.045A + 0.025B + 0.090C) - \$2.80 \text{ per ton.}$$

$$A = \$5.99 + 0.027A + 0.015B + 0.054C - \$2.80,$$

or

$$0.973A = \$3.191 + 0.015B + 0.054C, \text{ hence}$$

$$A = \$3.27 + 0.0154B + 0.055C.$$

$$\text{Thus the cost of iron} = \$9.9863 + 0.045 \times (3.27 +$$

$0.0154B + 0.055C) + 0.025B + 0.090C$ . If  $E$  = cost of iron per ton, we have

$$E = \$9.9863 + 0.147 + 0.0257B + 0.0925C.$$

$B$  and  $C$  cannot be eliminated until more values are determined, so this brings us to the discussion of the open hearth.

From Table I we have the following figures:

Material charged to open hearth, metallic	116,000 tons
Product from the open hearth	103,200 tons
Metallic scrap, i.e. pit and skull scrap, ingot butts, etc.	6,000 tons
Loss, metallic, i.e., metallic content of slags, etc.	6,800 tons

The distribution and values of the materials going into the above are given in Table XIV.

TABLE XIV

Material	Tons per Month	Base Cost per Ton	Cost per Month	Cost per Ton Steel
Hot metal	56,900	E	\$56,900.00E	\$0.551 E
Moulds and stools	1,920	\$25.00	48,000.00	0.4650
Iron scrap	760	20.00	15,200.00	0.1470
Home steel scrap	28,325	D	28,325.00D	0.274 D
Heavy bought scrap	2,535	13.00	32,955.00	0.3194
Light bought scrap	4,440	11.00	48,840.00	0.4734
Fine ore	9,260	2.80	25,928.00	0.2512
Cinder and scale	510	B	510.00B	0.0050B
Dolomite	3,170	2.90	9,193.00	0.0891
Limestone	7,100	1.05	7,455.00	0.0722
Lump ore	2,850	4.50	12,825.00	0.1242
Fluorspar	125	1.80	225.00	0.0022
Hot metal	9,260	E	9,260.00E	0.0897E
Ferromanganese	400	80.00	32,000.00	0.3100
Ferrosilicon	30	40.00	1,200.00	0.0116
Sulphur	10	35.00	350.00	0.0034
Coal. Dry powdered	100	2.00	200.00	0.0019
Aluminium	12	336.00	4,032.00	0.0391
Magnesite	140	25.00	3,500.00	0.0339
Chrome ore	55	16.00	880.00	0.0086
Clay	260	1.35	351.00	0.0034
Loam	450	1.10	495.00	0.0048
Coke	725	2.72	1,972.00	0.0191
Producer gas (coal)	23,920	1.88	44,969.00	0.4357

$$\text{Total} = \$290,680 + 66,160E + 28,325D + 510B.$$

The value of all steel scrap in the plant is signified by  $D$  at this point.

The products obtained from the material of Table XIV are:

Ingot and castings	103,200 tons
Ingot butts	1,700 tons
Pit scrap, etc.	4,300 tons
Run-off slag	3,100 tons
Ladle slag	4,100 tons
Normal slag	7,500 tons
Total slags	14,700 tons
Metallic scrap	6,000 tons

Thus the divisor for value of open-hearth slag is 123,900. In order to determine the cost of steel, the cost above materials is figured as given in Table XIVa.

TABLE XIVa—COST ABOVE MATERIALS—OPEN HEARTH

Account	Cost per Month	Per Ton (103,200 Tons)	Per Ton (123,900 Tons)
1 Steam	\$1,775.00	\$0.0172	\$0.0143
2 Water	700.00	0.0068	0.0056
3 Electricity	1,375.00	0.0133	0.0111
4 Transportation	5,000.00	0.0485	0.0401
5 Shops	9,285.00	0.0900	0.0750
7 Laboratory	1,400.00	0.0135	0.0113
8 Material in maintenance	2,500.00	0.0242	0.0202
9 General works	10,260.00	0.0995	0.0829
1 Refractories	2,700.00	0.0261	0.0218
2 Rebuilding	14,450.00	0.1401	0.1168
3 Store supplies	2,500.00	0.0242	0.0202
4 Contingent fund	3,190.00	0.0309	0.0258
1 Superintendents, melters, clerks	2,900.00	0.0281	0.0234
2 Stocking and charging, boxes	11,350.00	0.1101	0.0917
3 Charging furnaces, mixers, etc.	4,350.00	0.0422	0.0351
4 Melting and gas tending	17,550.00	0.1702	0.1419
5 Ladle lining	4,400.00	0.0426	0.0356
6 Calcining and alloy house	1,850.00	0.0179	0.0144
7 Mould handling	7,750.00	0.0751	0.0626
8 Scrap and cinder drop or skull cracker	7,000.00	0.0679	0.0565
9 Inspection, shipping and stripping	15,500.00	0.1503	0.1253
Total	\$127,785.00	\$1.2387	\$1.0319



Thus the cost of steel per ton in dollars =  $2.8162 + 0.641E + 0.274D + 0.005B + 1.2387$ . The cost of open-hearth slag =  $2.346 + 0.533E + 0.228D + 0.0041B + 1.0319$ .

But  $E$  = value found under blast furnaces; hence,

$$C = 3.378 + 0.533 \times (10.133 + 0.0257B$$

$$+ 0.0925C) + 0.228D + 0.0041B,$$

$$C = 3.378 + 5.40 + 0.014B + 0.049C + 0.228D + 0.004B,$$

$$0.951 C = 8.778 + 0.018B + 0.228D,$$

$$C = 9.24 + 0.019B + 0.24D$$

= value of open-hearth steel, slag and scrap.

It will be noted in Table I that open-hearth slag is used in the blast furnaces to the extent of 7200 tons per month, and produced at the rate of 14,700 tons per month (a material efficiency of 49 per cent), so that 7500 tons of open-hearth slag have no value. Allowing the open hearth due credit for the slag used in the blast furnaces, the cost of open-hearth steel is:  $290,680 + 66,160E + 28,325D + 510B + 127,785 - 7200C$ , or the cost per ton of open-hearth steel, which we will call  $F$  at this point, is:

$$F = \$4.055 + 0.641E + 0.274D + 0.0050B - 0.069C.$$

In order to arrive at the value of the scrap and scale from the mills, the accounts are tabulated in Tables XV and XVI.

TABLE XV—MILL ACCOUNT

	1A	1B	1C	2A	2B
1 Steam	\$6,500.00	\$8,970.00	\$3,640.00	\$6,760.00	\$780.00
2 Water	120.00	200.00	100.00	160.00	100.00
3 Electricity	500.00	325.00	75.00	225.00	75.00
4 Transportation		1,100.00	500.00	600.00	500.00
5 Shops	3,810.00	2,585.00	1,335.00	2,185.00	660.00
6 Roll shop	1,200.00	3,500.00	1,300.00	1,000.00	750.00
7 Laboratory	50.00	25.00	40.00	25.00	75.00
8 Store rooms	7,400.00	2,700.00	1,300.00	3,850.00	700.00
9 General works	3,400.00	4,030.00	1,465.00	2,930.00	1,100.00
1 Producing labor	4,300.00	9,950.00	3,600.00	7,550.00	2,900.00
Total	\$28,980.00	\$33,385.00	\$13,355.00	\$27,285.00	\$7,640.00
Rolls on (Tons)	66,000	56,800	14,100	36,900	10,500
Product	56,800	54,000	13,000	29,200	9,700
Scrap	8,000	2,500	1,000	7,100	750
Scale, etc	1,200	300	100	600	50
Cost of product per ton	\$0.510	\$0.618	\$1.027	\$0.934	\$0.788
Cost of product, scrap and scale per ton	0.439	0.586	0.947	0.739	0.728

TABLE XVI—ROLLING MILLS

Mill Account	1M Mill	2M Mill	3M Mill	4M Mill	5M Mill	Special Product
1 Steam	\$1,940.00	\$1,560.00	\$1,000.00	\$1,080.00	\$3,840.00	\$260.00
2 Water	80.00	80.00	40.00	40.00	120.00	
3 Electricity	500.00	500.00	290.00	300.00	1,000.00	
4 Transportation	300.00	300.00	200.00	200.00	400.00	200.00
5 Shops	655.00	770.00	170.00	185.00	825.00	
6 Rolls	300.00	600.00	300.00	300.00	1,500.00	
7 Laboratory	75.00	75.00	75.00	75.00	75.00	
8 Store rooms	750.00	850.00	400.00	500.00	1,250.00	
9 General works	730.00	740.00	370.00	380.00	730.00	360.00
1 Producing labor	9,600.00	9,800.00	6,075.00	7,200.00	8,935.00	1,450.00
2 Fuel	965.00	1,000.00	185.00	335.00	1,125.00	
Total	\$15,895.00	\$16,275.00	\$9,015.00	\$10,565.00	\$19,800.00	\$2,270.00
Rolls on (Tons)	8,000	9,000	1,550	2,800	8,500	2,200
Scrap	650	900	125	250	1,000	50
Scale	150	100	25	50	100	
Product	7,200	8,000	1,400	2,500	7,400	2,150
Cost per ton product	\$2.207	\$2.034	\$6.439	\$4.238	\$2.675	\$1.056
Cost per ton product scrap and scale	\$1.987	\$1.808	\$5.816	\$3.784	\$2.212	\$1.031

At this point it is necessary to follow the steel through its various rerollings.

The steel rolled in 1A Mill is rerolled in 1B Mill, and part of the product is then rerolled in 1C Mill. Product from 1B Mill is rerolled in 1M Mill and 2M Mill, and part of the product from 1C Mill is rerolled in 3M Mill and 4M Mill. Part of the product from 2A Mill is rerolled in 2B and part in 5M Mill. The special prod-

ucts are assumed to take their raw material from 2M Mill. Accordingly the values are tabulated in Table XVI, the scrap being figured direct, and remelted in the open hearth, and its value  $D$  being directly determined. In the case of roll scale, a metallic content of 65 per cent average is taken, the figures tabulated, being, however, metallic contents and not figured as the oxide.

TABLE XVII—VALUES OF SCRAP AND SCALE

Part of Mill	Scrap, Tons	Roll Scale	Value, per Ton	Total Cost
Open hearth	6,000		$\$0.24 + 0.019B + 0.24D$	$1440D + 114B + \$55,425.00$
1A mill	8,000	1,200	$F + 0.439$	$9200F + 4,038.50$
1B mill	2,500	300	$F + 0.439 + 0.586$	$2800F + 2,870.00$
1C mill	1,000	100	$F + 0.439 + 0.586 + 0.947$	$1100F + 2,169.00$
2A mill	7,100	600	$F + 0.739$	$7700F + 5,691.00$
2B mill	750	50	$F + 0.739 + 0.728$	$800F + 1,173.50$
1M mill	650	150	$F + 0.439 + 0.586 + 1.987$	$800F + 2,409.50$
2M mill	900	100	$F + 0.439 + 0.586 + 1.808$	$1000F + 2,833.00$
3M mill	125	25	$F + 0.439 + 0.586 + 0.947 + 5.816$	$150F + 1,167.50$
4M mill	250	50	$F + 0.439 + 0.586 + 0.947 + 3.784$	$300F + 1,726.70$
5M mill	1,000	100	$F + 0.739 + 2.212$	$1100F + 3,246.50$
Special product	50		$F + 0.439 + 0.586 + 1.808 + 1.031$	$50F + 193.20$
Total	28,325	2,675		$25,000F + 1,440D + 114B + \$2,943.50$

Table XVII gives the values of scrap and scale and from it we get

$$31,000 D = 25,000 F + 1,440 D + 114 B + 82,943.50$$

$$D = 2.676 + 0.806 F + 0.046 D + 0.0037 B$$

$$D = 2.812 + 0.847 F \text{ (since } B = 0.65 D)$$

We are now able to give Table XVIII, which gives representative real costs as they would be in the steel plant.

It will be seen from Table XVIII that flue dust costs really \$4.146 to make and many plants are spending one more dollar per ton to sinter this material, which brings the cost up to \$5.146 per ton. This material is expected to replace ore at \$2.80 a ton. It is quite apparent that this is doubtful economy.

TABLE XVIII—PRIME COST OF MATERIALS DETERMINED FROM THE FOREGOING

Material Cost per Ton	Equation	Prime Cost
Flue dust	$A \quad 3.27 + 0.0154B + 0.055C$	\$4.146
Pig iron	$E \quad 10.133 + 0.0257B + 0.0925C$	12.019
Open hearth slag	$C \quad 2.346 + 0.533E + 0.228D + 0.0041B$	14.841
Open hearth steel	$F \quad 4.055 + 0.641E + 0.274D + 0.005B - 0.069C$	15.371
Average steel scrap	$D \quad 2.812 + 0.847F$	9.991
Average roll scale	$B \quad 0.65D$	4.085

## TIME STUDY FOR VARIOUS WORKING UNITS

A blast furnace has a life of approximately 1,000,000 tons on one lining, and accordingly is idle at the end of a period of six years. In order to completely repair a furnace after such a run, a period of approximately four and one-half months is required. Thus the time lost for rebuilding purposes is 5.88 per cent of the total time from blowing-in to blowing-in. In a plant involving six furnaces there would be lost a total of twenty-seven furnace-months for the relining in a period of six years so that this non-productive period is of material consideration, or 6.2 per cent of the working time.

An open-hearth furnace has a working period of approximately 400 heats, and approximately one month's time is consumed each year for rebuilding, so that this rebuilding period represents 8.5 per cent of the time from run to run, although including the time required for replacement of one roof.

The rolling mills are all subject to mechanical repairs, not being affected chemically as the blast and open-hearth furnaces. The heating furnaces in conjunction with a rolling mill are subject to the wearing out due to chemical changes, and the pit furnaces as operated, representing eleven units, are subject to one

pit down for repairs continually, leaving ten in operating conditions, so that to these heating furnaces 9 per cent of the time is consumed in rebuilding.

In connection with all of the units unavoidable delays are present, such as tapping time, i.e., when the furnace is not being used due to blast off, mechanical delays affecting all units, roll change time during the time when mill should be working, etc., etc., all of which should be subject to investigation. In Table XIX there is also included the operation period of a thirty-day month, wherein the blast furnaces are in continuous operation, the other units being allowed four Sundays or the equivalent off per month.

TABLE XIX—PERIOD OF 30-DAY MONTH

Unit	Number	Rebuilding, per Cent	Perfect Time per Unit, Hours	Perfect Time Gross, Hours	Unavoidable Delays, Hours
Blast furnaces	6	6.2	720	4,320	72
Open hearth	32	8.5	624	19,968	192
Strippers	2		624	1,248	
Soaking pits	11	9.0	624	6,864	
1A mill	1		624	624	26
1B mill	1		624	624	78
1C mill	1		624	624	13
2A mill	1		624	624	54
2B mill	1		624	624	13
1M mill	1		624	624	67
2M mill	1		624	624	91
3M mill	1		624	624	39
4M mill	1		624	624	67
5M mill	1		624	624	104

The following time studies are averages of observed conditions and are representative:

TIME STUDY FOR BLAST FURNACES

Number of Units	Operation	Lost Time Rebuilding, per Cent	Lost Time Unavoidable, per Cent	Working Efficiency, per Cent
6	Continuous	6.2	1.66	92.14

TIME STUDY FOR OPEN HEARTH

As noted in Table XIX, the lost time due to rebuilding is 8.5 per cent of the working time, so that out of a plant of thirty-two furnaces there are twenty-nine furnaces in continuous operation, giving some 7950 ingots a week, and making some 317 heats of twenty-five ingots each. The figures in time are in parts of an hour.

TABLE XX

	Per Month	Per Cent	Hours per Heat
Units	32	100.0	
Off rebuilding	3	8.5	
Operating	29	91.5	
Heats	1,373		
Gross time, 32 units	19,968		
As run, 29 units	18,080	100.00	
Rebuilding loss	1,888		
Unavoidable delays	192	1.06	
Net working time for 29 units	17,888	98.94	
Charging	3,199	2.33	
Melting	9,721	7.08	
Tapping	344	.25	
Casting	343	.25	
Total operations, 13,607 hours			
Time of operation of 29 units per month	= 18,080 hours	100.00	
Time lost not chargeable to operation	= 192 hours	1.06	
Actual time consumed in functions of furnace	= 13,607 hours	75.26	
Thus the working efficiency of the open-hearths as run (29)		75.00	
And the working efficiency of the plant (32 furnaces)		68.00	

## STRIPPERS

The plant contained two strippers, and the following are noted performance:

	Per Month Hours	Per Heat Hours	Per Cent
Transfer from poring stand to strippers	220	0.16	
Stripping	563	0.41	
Heats stripped	1373	1	
Hours in month	624		

Number of heats stripped if the operation were continuous = 1522 by one machine, or 3044 for the pair of strippers.

Working efficiency of two strippers =  $1373 + 3044 = 45.1$  per cent.

## SOAKING PITS

A soaking pit of four holes will hold approximately one heat of twenty-five ingots, and out of a plant of eleven pits, one set will be off for rebuilding, so that ten pits are in continuous operation.

	Per Heat, Hours
Second transfer from the strippers to pits	0.08
Charging in Pits	0.39
Soaking	1.02
Drawing pits	0.42
Bottom making	0.20

Total time cycle from full to empty pits, excluding the transfer, is approximately two hours per heat.

Thus one set of pits will accommodate twelve heats per day in continuous operation. And ten sets of pits will accommodate 120 heats per day.

The actual average performance of ten pits for the ingots from the twenty-nine open-hearth furnaces as operated was at the noted tabulated rate of fifty-three heats per day of 24 hours.

Working efficiency =

$$\frac{\text{Actual accommodation}}{\text{Maximum capacity}} = \frac{53}{120} = 44\%$$

## ROLLING MILLS

The following are average results such as may be expected from the usual rolling mill plant:

	Per Heat, Hour	Tons Rolled per Hour
Transfer from the pits to the rolling mill table	0.20	
Rolling in 1A mill to bloom	0.48	152
In bloom shears, cropping and making 2 blooms	0.28	

The average heat is taken as 73 tons and of 25 ingots per heat, and as the slowest operation is the tonnage determining, the capacity is the time of this operation in hours divided into the tonnage for that time.

From Table XIX it will be noted that such a mill operating for one month has 26 hours down due to unavoidable delays, such as roll change, mechanical breakdown, etc., coming at extraordinary time, which leaves 598 hours for working, out of a possible 624 for perfect time. Ordinarily roll changes on such a mill should take place on the Sunday time.

Thus the actual working hours—598 times 152 tons = 90,000 tons—is the maximum capacity for continuous operation.

The actual average tonnage of such a mill is noted as 66,000 tons.

Thus the working efficiency of 1A Mill = 73%.

## 1B MILL

The two blooms from 1A Mill delivered to the rougher of 1B Mill are rolled simultaneously, delivered to 1 Stand, where one is rolled into billet form and one into the rough billet for shape. Thus 1 Stand has the same capacity as the rougher. On account of the lengthening out of the rolled material from pass to pass, the capacity of such a mill is limited to the time of the longest pass.

From 1 Stand there would be delivered one billet finished to 4" x 4" section, and the rough shaped for



the other stands of 1B Mill. The 4x4 section can either become commercial billets being sheared to salable length, or the raw material for 1C Mill. Thus the following time study comes in:

TABLE XXI

Part	Time in Hours per Heat of 73 Tons, 25 Ingots	Tons Rolled On per Hour (By Time Consuming Operation)
Two blooms in rougher.....	0.47	.....
Rougher.....	0.50	146
1 stand.....	(2 pieces)	.....
2 pass.....	0.125	.....
3 pass.....	0.175	.....
4 pass.....	0.250	.....
5 pass.....	0.400	.....
6 pass.....	0.550	132
Billet shears for part product No. 1 stand.....	0.825	88
1C mill, complete.....	0.825	88
Sawing product from No. 6 pass.....	0.250	.....

## TIME STUDY OF 1B AND C MILLS

Since all of the product passes through the rougher and 1 Stand it is evident that there must be an alteration between the 4x4 shears and the 1C Mill, for maximum production, of all three considerations, so that one billet would go into 4x4 while rolling for the 1B Mill, and the next following billet go to the 1C Mill.

From the above it follows that as there are 624 possible hours in a month, and from Table XIX 78 hours are deducted for unavoidable delays, the remaining 546 are tonnage rolling hours, which at 132 tons per hour for the 1B Mill slowest pass gives 72,072 tons as the maximum capacity.

Thus capacity = 72,000 tons, while the actual performance is 56,800 tons, hence working efficiency of 1B Mill = 78%.

1C Mill, working 624 less 13 hours for unavoidable delay, gives 611 tonnage rolling time, which at 88 tons per hour is 53,768 tons per month.

The actual material rolled on for such a mill averages 14,100 tons, so that the working efficiency of such a mill is 26%.

As worked alternately giving product to the 1C Mill, the 1B Mill capacity is limited to the time of pass 1 only, which rolls two blooms down at the same time, having a capacity of 146 tons per hour. With tonnage rolling time of 546 hours, this capacity is 79,716 tons per month.

Thus the working efficiency at maximum capacity = 73%.

## TIME STUDY FOR 2A AND B MILLS

The performance of 2A Mill will be different from 1A Mill on account of the different product desired, involving greater reduction by the mill from ingot to finished bloom or slab. The following table is representative of time consumed in the operations. Time in hours:

	Per Heat	Tons Rolled on per Hour
Transfer of ingot from soaking pits to rolling mill table.....	0.200	.....
Rolling in 2A mill to bloom or slab.....	0.910	80
Transfer to shears.....	0.625	.....
Shearing, average.....	0.750	.....

The working time of 2A Mill averaged as follows:

	Hours
Total available hours per month.....	624
Unavoidable delays.....	54
Net rolling time.....	570

570 hours' rolling time at 80 tons per hour, for the time-consuming operation in the rolling mill, is 45,600 tons per month.

The average performance of the mill is 36,900 tons rolled on per month.

Hence the working efficiency of 2A Mill =  $36,900 \div 45,600 = 80\%$ .

Part of the product of 2A Mill is rerolled in 2B Mill into small billets.

	Per Heat	Tons per Hour
Transfer from rolling mill to 1 stand of 2B mill.....	0.650	.....
Time to roll in 2B mill, rolling on a bloom sheared into two pieces.....	1.000	73
Transfer from 2B mill to hot beds.....	0.400	.....

The time-consuming operation rolled at the rate of 73 tons per hour, and the total available rolling time for such a mill is 624 hours, less 13 hours for roll change, repairs of mechanical defects, etc., giving a net rolling time of 611 hours. Thus the maximum capacity of such a mill is 44,600 tons per month.

The actual performance for the mill averages 10,500 tons rolled on per month.

Hence the working efficiency is  $\frac{10,500}{44,600} = 23.5\%$ .

All of the products of the above mills are allowed to cool, and then transported to the merchant mills. The heat lost would be valuable if the products could be utilized at once in the bar mill furnaces, and proper placement of such mills could utilize such heat efficiently.

## TIME STUDY OF MILLS, 1M TO 5M

Table XXII gives the working efficiency of the bar mills.

The time consuming pass or operation is taken as guide to maximum capacity.

TABLE XXII—TIME STUDY OF THE BAR MILLS

Mills	1M Mill	2M Mill	3M Mill	4M Mill	5M Mill
Heating furnaces, minutes.....	40	40	30	40	40
Time determining pass, in seconds.....	35	80	36	80	45
Average weight of billet, lb.....	300	1200	80	220	800
Capacity of slowest pass in tons per hour.....	16.6	22.7	3.57	5.8	28.6
Time for 1 ton, hours.....	.060	.044	.280	.171	.035
Total hours in month.....	624	624	624	624	624
Unavoidable delay.....	66	91	39	67	104
Net rolling time.....	558	533	585	557	520
Maximum tonnage per month.....	9,230+	12,100+	2,088	3,230+	14,800
Average actual tonnage per month.....	8,000	9,000	1,550	2,800	8,500
Working efficiency.....	86%	74%	74.2%	86%	57%

The diversity of product rolled on such mills naturally retards the product and the obtaining of maximum capacity of material rolled on. A gage to this diversity would be the amount of roll change that such mills are subject to.

In order to appreciate what the attainment of more perfect working efficiency would mean, the two tables, XXIII and XXIV, attached for a summary of the foregoing, should be given due consideration.

These figures of Tables XXIII and XXIV give an idea as to what betterment of mechanical working and organization would do toward economy in the rolling mill.

The valuations of product are not market values, as the cost figures are not those of product but of the amount of material handled, rolled on, etc., and thus are prime costs representing the handling of all ma-

TABLE XXIII—SUMMARY

Part of Plant	Working Efficiency	Prime Cost per Ton Rolled On	Tons Material per Month	Cost of Handling	Cost as if at 100 Per Cent Efficiency	Difference
Blast furnaces	92.14	\$12.019	80,100	\$962,200.00	\$1,044,000.00	\$181,800.00
Open hearth	68.00	15.371	103,200	1,586,200.00	2,333,000.00	746,800.00
Strippers	45.10	0.016	103,200	1,651.00	3,669.00	2,018.00
Soaking pits	44.00	0.095	102,900	9,775.00	22,217.00	12,442.00
1A mill	73.00	0.439	66,000	28,975.00	39,690.00	10,715.00
1B mill	78.00	0.586	56,800	33,285.00	42,675.00	9,390.00
1C mill	26.00	0.947	14,100	13,350.00	51,340.00	37,990.00
2A mill	80.00	0.739	36,900	27,270.00	34,085.00	6,815.00
2B mill	23.50	0.728	10,500	7,645.00	32,560.00	24,915.00
1M mill	86.00	1.987	8,000	15,895.00	18,480.00	2,585.00
2M mill	74.00	1.808	9,000	16,270.00	21,989.00	5,719.00
3M mill	74.20	5.816	1,550	9,015.00	12,180.00	3,165.00
4M mill	86.00	3.784	2,800	7,400.00	8,605.00	1,205.00
5M mill	57.00	2.212	8,500	38,430.00	67,420.00	28,990.00
Special products		1.031	2,200	2,268.00		

Maximum possible saving per month

TABLE XXIV—THE MATERIAL EFFICIENCY OF SOME PRODUCTS

Material	Where Made	Amount per Month, Tons	Recharged, Tons	Accumulative, Tons	Efficiency of Recovery, Per Cent	Prime Cost per Ton	Prime Value of Materials as is the Custom to Utilize	Prime Value of the Materials Discarded
Flue dust	Blast furnaces	8,200	3,600	4,600	44	\$4.146	\$14,925.00	\$19,071.00
Slag	Blast furnaces	48,100	None	48,100	6.946			334,102.00
Metal scrap	Open hearth	6,000	6,000	None	100		See metal scrap	
Slag	Open hearth	14,700	7,200	7,500	49	14.841	106,835.00	111,307.00
Metallic loss	Open hearth	6,800	1,080	5,720	16	14.841	16,028.00	85,890.00
All metal scrap in plant	All departments	28,325	28,325	None	100	9.991	283,250.00	
Roll scale metal content	All departments	2,675	1,631	1,044	60			
Roll scale	All departments	4,011	2,510	1,501	60	4.083	10,253.00	6,131.00

terials. Any betterment would naturally increase the profit, due to greater credits and less net cost of the products salable. Some of the figures for single departments warrant the so-called research action, but the problems are more of a kind to be solved by a planning department than by chemical or mechanical experts. In spite of the relatively great material efficiency of the average steel plant, the fact that much time is lost and the working efficiency of some departments is low, makes the problem one for a staff of men, and not the work of the single manager or man directly in charge of a single producing unit. Each and every department's close co-operation is essential for the approach to 100 per cent working efficiency. This calls for planning, routing and grouping of work, even though the materials handled run into the thousands of tons daily.

In all of the above calculations it will be noted that the figures for mill rolling performance relate to the material rolled on and not the product obtained. This method gives a definite means of obtaining capacity, while it would not be so if the product obtainable from such mills were taken as the basis. Product in turn will be determined by the quality of the material rolled on, the skill of the operatives, etc.

It is the practice in rolling steel to compensate many employees by piece work or tonnage production, but in order to obtain maximum production it is quite obvious that the working efficiency is a figure of great importance, and this should not be kept hidden. With scarcity of labor becoming a paramount factor in all industries, the working efficiency of all mechanical appliances, from machine tools to blast furnaces, is something to be reckoned with, and it seems that there is a profitable field of endeavor in the steel industry for the planning room and for planning systems such as practised in the production of mechanical and electrical finished products, taking this function away from the man-driving managers so often in steel plants.

The Taylor Instrument Companies, Rochester, N. Y., are building a new up-to-date power plant containing automatic stokers, electric coal and ash handling equipment; coal, water and steam weighing and measuring instruments.

## Large Increase in By-Products from Coke Ovens

Statistics as to the recovery of by-products from coke ovens in the United States in 1915, contained in a report recently issued by the Geological Survey show the tremendous growth of the by-product coke industry up to the end of 1915. The value of the by-products in 1915 was nearly \$30,000,000 as compared with a previous high value of \$17,500,000 in 1914. The greatest increase was in benzol products whose value rose from less than \$1,000,000 in 1914 to more than \$7,760,000 in 1915. Benzol has been recovered in this country from coke-oven gas for a number of years but prior to 1915 the market was small and the price low. The following table shows the amounts and value of the various products recovered. The increase in by-product coking has been very great since the beginning of this year and production is far in excess of the 1915 figures.

BY-PRODUCTS OBTAINED FROM COKE-OVEN OPERATIONS IN 1915

Product	Quantity	Value	Average Value
Tar obtained and sold, gallons	138,414,601	\$3,568,384	\$0.026
Ammonia obtained and sold:			
Sulphate, pounds	199,900,487	5,648,958	.028
Liquor, gallons	10,626,612	1,240,473	.117
Anhydrous, pounds	30,002,196	2,978,044	.099
Gas produced, M cubic feet	213,667,614		
Surplus gas sold or used:			
Illuminating, M cubic feet	17,196,426	3,083,311	.179
Domestic fuel, M cubic feet	27,590,624	3,158,129	.114
Industrial fuel, M cubic feet	39,568,864	2,383,459	.060
Benzol products:			
Crude light oils, gallons	13,082,678	4,304,281	.33
Secondary light oils, gallons	182,039	28,731	.16
Benzol, gallons	2,516,483	1,428,323	.568
Toluol, gallons	623,506	1,529,803	2.45
Solvent naphtha, gallons	196,151	46,233	.24
Naphthaline, pounds	465,865	46,959	.10
Other products*		379,491	....
		\$29,824,579	
Coke, short tons	14,072,895	48,558,325	3.45
		\$78,382,904	

\* Includes breeze, retort carbon, domestic coke and coke dust, and aniline oil.

These by-products were obtained by the carbonization of 19,500,000 tons of coal, from which 14,000,000 tons of coke was obtained.



## Mechanical Engineering of a Synthetic Phenol Plant

BY FREDERICK POPE

The chemistry of synthetic phenol is so generally understood that I will not go into it.

Our general plan is to sulphonate benzol, make the calcium salt, convert that to the sodium salt and fuse with caustic soda, decomposing the sodium phenolate with a mineral acid and refining the phenol by distillation.

### STORAGE OF BENZOL AND ACID

The storage tank for benzol must be of ample capacity, closed, of iron and located in a building that can be heated in winter. The building should be well ventilated and electric light bulbs enclosed in airtight or marine fixtures. The benzol should be pumped to the measuring tanks. If the pump is a steam pump, it should be built with a long spacer separating the water end from the steam end. It is a good plan to run this benzol pump with compressed air. It is unwise to handle the benzol with a monteju unless special precautions are taken. This benzol house should be so located as to avoid exposure of this building to fire or sparks caused by passing engines, etc.

Sulphuric acid storage should be of ample capacity. The tanks should be located in a building that can be heated during the winter months. Sulphuric acid can be handled from the storage building to the measuring tanks with a monteju. When convenient, I prefer to force the acid from the storage tanks to the monteju with compressed air, although it is a good practice to draw the acid from the bottom of the tank through an opening in the bottom of the acid tank. This, however, is open to the objection that it is difficult to replace a valve unless the tank is emptied of acid. The building must be well ventilated and the floor provided with drains connected with a sewer so that the floor may be washed off. If possible, both the benzol and sulphuric tanks should be below the track level to allow filling of the tanks by gravity.

### MEASURING TANKS

The measuring tanks should be of ample capacity. The sulphuric acid and benzol may be measured by volume, but I very much prefer to mount the measuring tanks on scales, connecting the scales with the pipes to the sulfonating kettle through a spring coil so that the acid or benzol may be weighed. This not only insures accuracy in the process, which may or may not be important, but is economical, which is a consideration with high-priced benzol and sulphuric acid.

There should be a measuring tank for benzol and one for sulphuric acid; these tanks should be vented through the roof. The sulphuric acid tank should be provided with a seal which will dry the air entering the tank.

My general plan is to arrange the tanks so that they shall be filled to an approximate amount; then the scales are adjusted with weights until they balance. One of these weights should represent the exact weight of the charge desired. After the scales have balanced, this weight should be removed and the acid or benzol allowed to run into the sulfonating kettle until the scales balance again and then the supply promptly shut off.

I arrange this by having an indicator from the scale directly in front of the valve controlling the flow from the measuring tank to the sulfonating kettle, having separate inlets for sulphuric acid and benzol, thus enabling the operator to control the supply promptly.

Each sulfonating kettle is equipped with a reflux condenser of the single-pipe type; in form it should be a coil of pipe contained in a tank, which tank is pro-

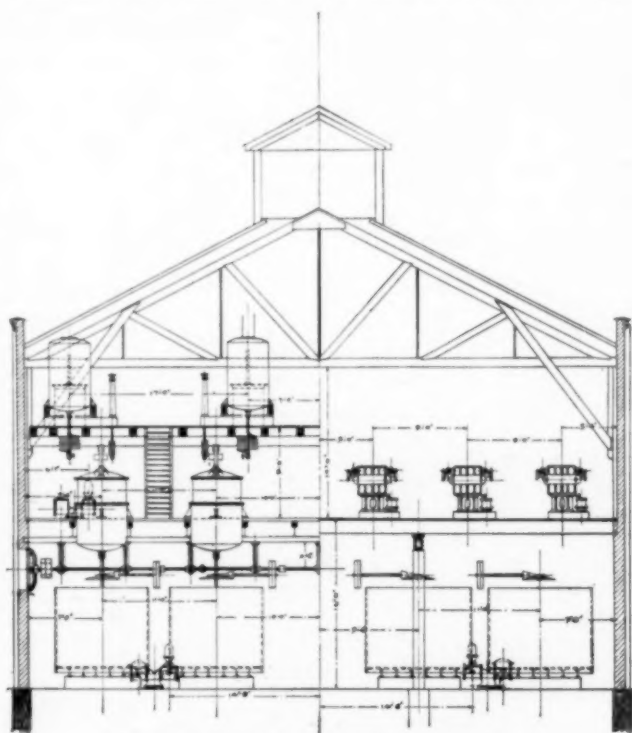
vided with a water inlet and outlet, the condensing coil is extended at the bottom to connect with the sulfonating kettle and at the top to extend through the roof, the coil so arranged that vapors condensed therein will drain back into the sulfonating kettle.

This coil should be of ample area to give free vent from the sulfonating kettle through the roof out of the building and ample surface to condense the maximum amount of vapor it might receive.

### SULFONATING KETTLE

The sulfonating kettle is made of cast iron. Some of the special irons made by various manufacturers have advantages over ordinary cast iron.

The ratio of depth to the diameter must be carefully considered, the depth being somewhat greater than the diameter. The shape of the bottom must also be care-



CROSS-SECTION OF BENZOL BUILDING

fully considered on account of the relation it has to the agitator.

The agitator should be of the propeller type without a bearing at the bottom. I prefer the propeller type of agitator with a single propeller working in a tunnel. The shaft should be of ample size and the propeller shaft and driving pulley carefully balanced.

I prefer to drive the agitator with a belt directly to a pulley on the agitator shaft rather than through bevel gears as is often done. This can be arranged by using quarter turned belt.

The kettle should be provided with a manhole of ample size in the cover and with a thermometer tube extending nearly to the bottom. The thermometer should be a recording thermometer with a flexible connection between the kettle and the instrument. The space between the thermometer bulb and the inside of the thermometer pipe should be filled with precipitated copper or with a mixture of graphite and precipitated copper.

The kettles are steam-jacketed. The steam jacket need not extend more than two-thirds of the height of the kettle. The steam jacket should be provided with a safety valve.

The steam to the jacket of the kettle should enter

through a reducing valve, or a much better arrangement is to use low-pressure exhaust steam.

Cold water should be piped to jacket to cool off accidentally overheated charge.

The steam jacket is connected at the bottom through a pipe to a steam trap. Each sulfonating kettle should have its own steam trap.

The sulfonating kettle may be discharged by using compressed air into the top of the kettle and blowing the charge out through a pipe extending to the bottom, although a much better arrangement, and one that should be used whenever possible, is to have the discharge pipe from the bottom of the kettle, this will pass through a stuffing box in the kettle jacket and is provided with a valve as close as possible to the kettle.

#### LIME MIXING TANKS

Lime mixing tanks must be of ample capacity. The lime mixers should be iron tanks provided with a powerful stirring device and equipped with an iron basket made in the shape of a segment or a circle, the short dimension of which is  $\frac{1}{4}$  the depth of the tank. The depth of the baskets is about  $\frac{1}{4}$  the depth of the tank; they may be made of thin plate punched full of small holes or of wire mesh.

The mixer must be piped to receive either hot or cold water and steam. Steam is introduced near the bottom of the tank through a circulating jet.

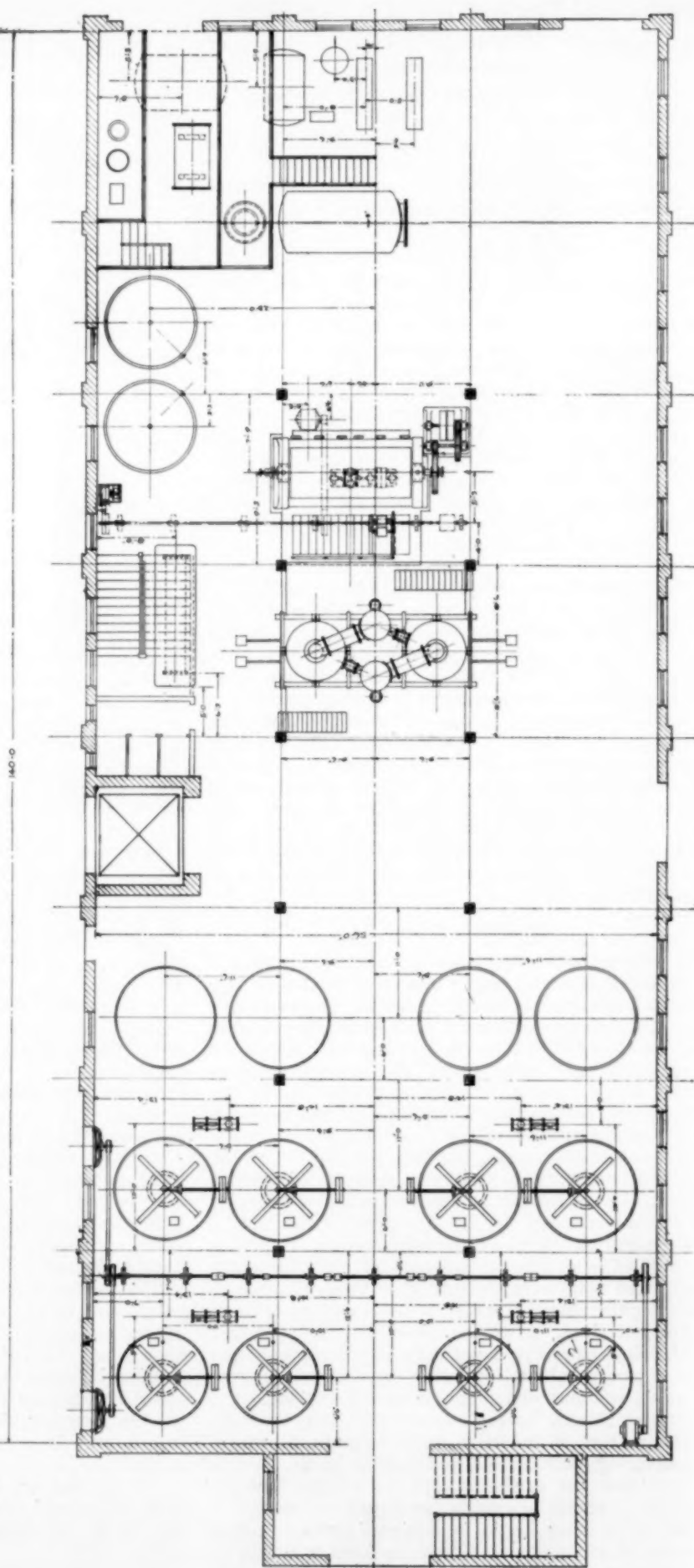
The tank should be set at such an elevation as to allow the milk of lime to flow to the lime mixing tub by gravity. Pipe connection between the lime mixing tanks and the liming tubs should be as short and as straight as possible and so arranged that the pipes will drain and may be blown out if necessary.

#### LIMING TUBS

Liming tubs, one for each sulfonating kettle, are made of iron or yellow pine, equipped with a stirring device. The stirring device should be of iron, preferably cast iron.

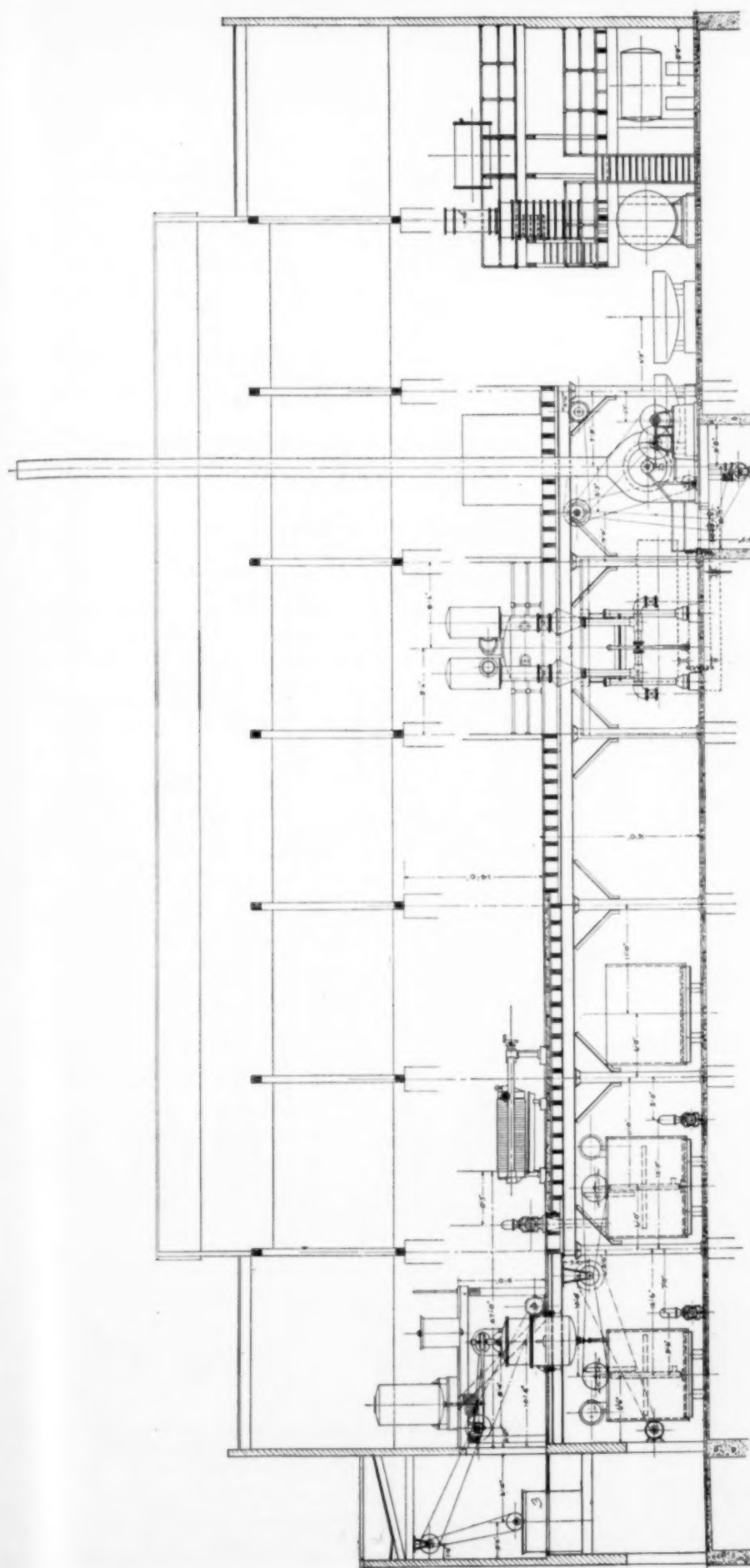
These tanks are to be located near the sulfonating kettles, piped with cold water and equipped with lead coils on the inside through which cooling water may be circulated.

The liming tubs must be



BENZOL BUILDING—FIRST FLOOR PLAN





LONGITUDINAL SECTION OF BENZOL BUILDING, SHOWING APPARATUS AND MACHINERY

equipped with steam supply to heat the contents of the tub. Steam should be introduced near the bottom, preferably through a circulating heater jet. The outlet should be as close as possible to the bottom and on the side of the tank.

Either a pump or montejus may be used to supply the filter presses. If a montejus is used, it must be below the tanks so that it can be filled by gravity. If a pump is used, it should be supplied with bronze rods. The connection between the pump or montejus and the liming tubs and between the pump or montejus and filter press should be of ample area and as short and straight as possible, provided with means for blowing out. There should be at least one pump or montejus for each two liming tubs.

#### LIME FILTER PRESSES

The filter press, which should be the wash type, may be either plate and frame or one of the patented type. I prefer the plain plate-and-frame presses, the frames being designed for a 2-inch thick cake.

There should be ample filtering capacity. The filter presses should be located above the soda tubs.

The best type of filter press for this work is the side inlet type, which does not require holes in the plates or cloths but in which the liquid to be filtered enters through holes in the side lugs and the wash water through holes in the side lugs on the other side.

The press is piped so that it may be washed with either hot or cold water and blown with either air or steam. The discharge from the press is arranged so that it may be discharged to the sewer or to the soda tubs.

## SODA TUBS

Soda tubs, one for each sulfonating kettle, are made of iron or yellow pine, equipped with a stirring device. The stirring device should be of iron, preferably cast iron.

These tanks are located on the same level with the liming tubs below the filter presses. They should be equipped with indirect heating coils as well as means for heating with live steam similar to the liming tub. The outlet should be as close to the bottom as possible on the side of the tank.

Either a pump or montejus may be used to supply the filter presses. If a montejus is used, it must be below the tanks so that it can be filled by gravity. If a pump is used, it should be supplied with bronze rods.

The connection between the pump or montejus and the liming tubs and between the pump or montejus and the filter press should be of ample area as short and straight as possible, provided with means for blowing out. There should be at least one pump or montejus for each two soda tanks.

## SODA FILTER PRESSES

These are arranged the same as the lime filter presses and all remarks about the filter presses apply here, except that the filter presses are arranged to discharge into either sewer or storage tanks.

The cake from both sets of filter presses is caught in a car mounted on wheels, arranged so that it can be dumped through a chute into a car to receive the cake outside.

It is possible, and in some cases desirable, to have a hopper below the filter press extending the length of the plates and frames so that the cake may be discharged through this hopper into a cart or car below to take it away. Either method admits of economic handling of the filter cake.

## STORAGE TUBS

Storage tubs to hold the weak sodium benzol sulfonating solution may be of iron or yellow pine; I prefer to use yellow pine. They must be of ample capacity, large enough to hold at least three days' production of weak liquor.

## EVAPORATORS

In a large plant, it is advisable to use a multiple-effect evaporator although in a small plant it is better to use a single effect.

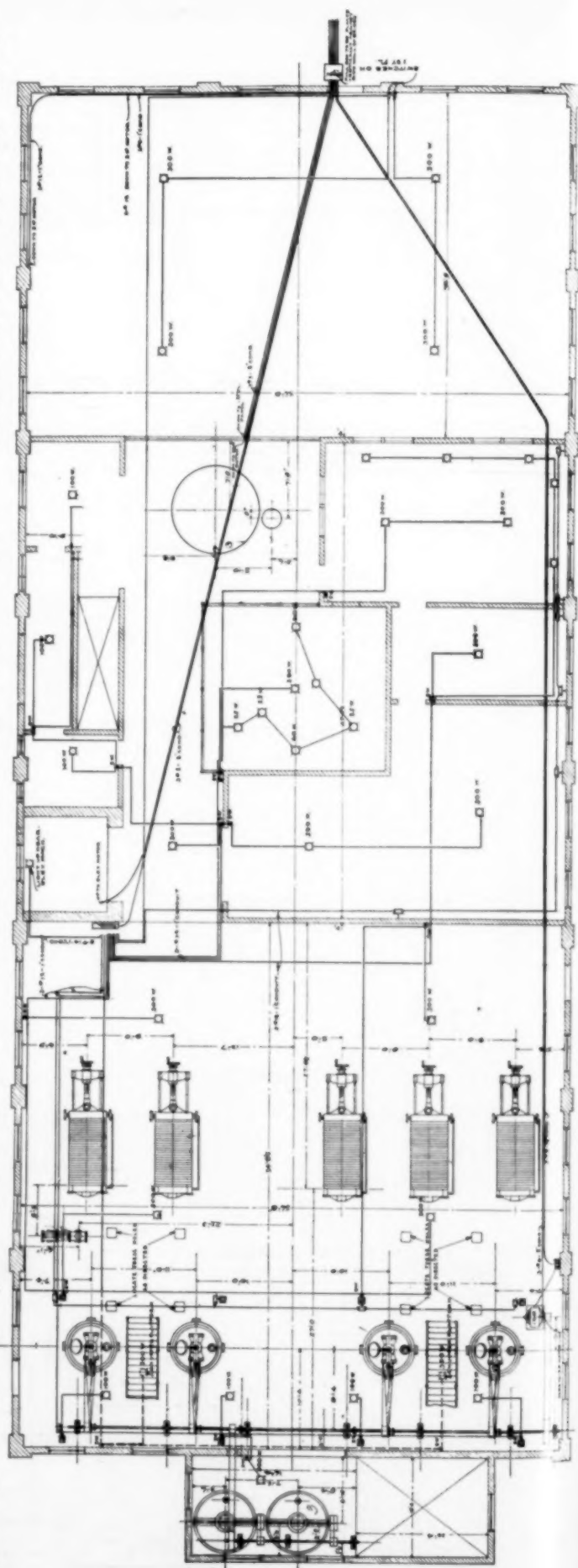
There has been considerable mystery made about evaporators for sodium benzol sulfonate. Any standard machine does the work provided the construction of the machine allows a free and easy circulation of the boiling liquor. Obstructed circulation of liquor will cause the evaporator to scale and lose its efficiency.

A vertical tube, vertical-shell basket-type of evaporator with a splash plate over the basket is the best type to use.

It is a good plan to make the bottom head hinged so that it may swing clear, giving easy access to the tubes for cleaning. However, this is really unnecessary, although desirable, if ample manholes are provided, as the evaporator should run four months without being cleaned.

The shell must be provided with peep holes, gage glasses, etc.

Between each effect and between the final effect, and the air pump, catch-alls or separators must be used to catch any entrained liquid going over with the vapor and so piped that this entrained liquid will be led back to the body of the evaporator.





The vacuum pump is of the ordinary type of wet vacuum pump and condenser.

The condensed water pump is the ordinary stock type.

The heavy liquor pump is of the Magma pump type; the standard stock patterns of the various pump companies are suitable. Steam pumps are preferable as they are less noisy in operation. It is wise to provide a spare Magma pump, and in a large plant a spare vacuum pump.

A very good arrangement, and one which can be easily made in the case of a double-effect evaporator, is to so pipe the apparatus so that it can be run as a double effect or either shell as a single effect.

In case of a triple-effect evaporator, it is easy to arrange the piping so that it may be run as a triple effect or with any two baskets as a double effect. The object of this is to permit cutting out of any shell for cleaning or repairs without affecting the capacity of the plant.

The heating surface should be designed to evaporate the required amount with 15 lb. pressure as the evaporator should be piped to the 15-lb. line, of which I will speak later.

The heavy liquor from the evaporator is discharged by a Magma pump to the heavy liquor storage tank which is a closed iron tank well covered with insulating material, equipped with steam-heating coils in the bottom and of sufficient capacity to hold three days' output.

The pipe from the Magma pump to the storage tank should be as short and as straight as possible without pockets and arranged so that it may be blown out. The heavy liquor storage tank is located over the drier so that it will feed to the drier by gravity.

#### SALT DRIER

There are a number of methods of drying the heavy liquor. It may be accomplished with a mechanical drier of the drum or disc type or by drying in open pans.

It is possible, of course, to crystallize the benzol sulphamate out of the solution, but that method is open to many objections and I will eliminate it from this discussion.

The best means that I know of is to use a rotary drum drier. It is economical of labor, delivers crystals of a suitable size for fusion, and above all, produces a salt containing a uniform amount of moisture. This is important, for, unless the percentage of moisture in the salt going to the fusion kettles is known, the amount of actual salt used cannot be known.

#### SALT CONVEYING SYSTEM

The salt from the drum drier discharges over an apron into a screw conveyor parallel to the drum. This screw conveyor discharges into a bucket and belt elevator which discharges the salt on to a conveyor of either screw or belt type and carries it into the fusion building where it discharges into a bin of ample capacity. The salt is drawn from the bottom of the bin into galvanized iron cans—ordinary ash cans being used for this purpose, each can holding 100 lb. salt.

All the foregoing apparatus should be in one building in which there is not any fire or flame of any sort, except the salt storage bin, which is in a second building entirely separate from the first and a short distance from it. This second building will contain the apparatus next described.

#### FUSION KETTLES

Fusion kettles are cast-iron kettles. The special mixtures of various manufacturers have some advantage over the ordinary cast iron. The kettles are of elongated hemispherical shape and set in a steel shell lined with brick with a layer of asbestos between the brick

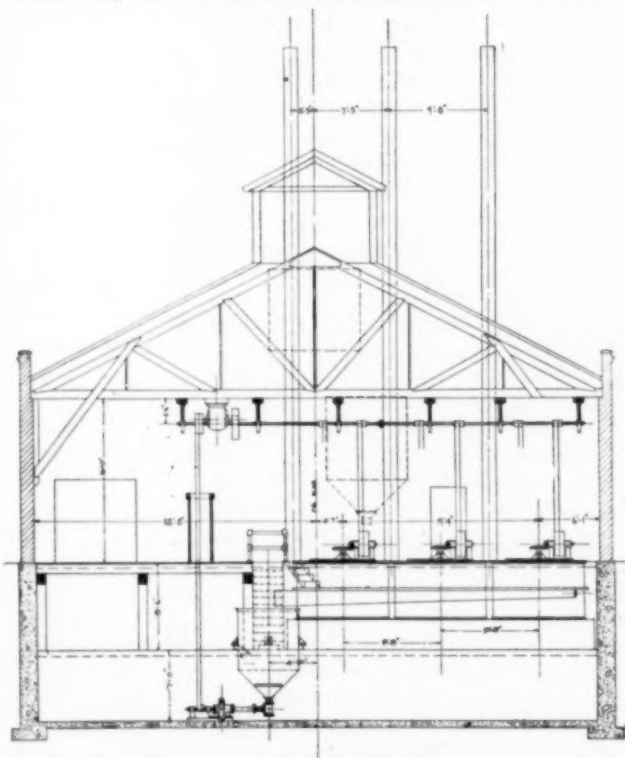
and the shell. The kettles rest on an iron top which is supported by the shell and to a certain extent by the brick work.

These may be heated by oil, gas or coal. Oil, however, is the most satisfactory.

There should be a combustion fire pot at the bottom of the setting of smaller diameter than the brick lining. The flame should strike this fire pot tangentially so as to give the gases a whirling motion in the furnace.

The kettles are equipped with a powerful stirring device of cast iron of modified horse-shoe type, that is, the blades are bent backwards in opposite direction so that they will throw the molten mass upward as well as around. It is a good plan to equip these kettles with breakers to further agitate the whirling mass.

The kettles are equipped with a thermometer tube, which may be of double extra heavy pipe with end



CROSS-SECTION OF FUSION BUILDING

welded or preferably of a rod of wrought iron bored out with a gun bit. The thermometer should be of the recording type with a flexible connection from the bulb to the recording instrument.

The kettles may be discharged through a bottom opening or by lading out the fused mass. I have found the latter method to be the more satisfactory. The disadvantages of a bottom discharge more than outweigh its evident advantages.

The best general arrangement of the fusion kettles is to have them level with the floor so that the caustic soda and the salt may be charged into the kettle from the floor level. The kettles should be arranged in two rows with the floor level lower than the main floor level between them.

#### METHOD OF HANDLING FUSED SODIUM PHENOLATE

In the center of the space between the rows of kettles, a trough extends from one end to a conical-bottom tank at the other. This tank is provided at the bottom with a grid covered with a wire screen and at the bottom of the cone with a centrifugal pump discharging into the other end of the trough. When this tank is nearly filled with water and the centrifugal

pump started, it discharges a stream of water into the far end of the trough running back into the tank.

The hot fused sodium phenolate and excess of caustic, without any previous cooling, can be ladled from the kettle directly into the water in this trough, which readily dissolves the same. When a kettle has been entirely discharged the system is arranged so that the pump will discharge into the decomposing tanks.

#### WEAK ACID TANKS

These are yellow pine or cypress tanks, lead-lined, located over the decomposing tanks or acidulators. The space over these tanks must be well ventilated.

#### DECOMPOSING TANKS OR ACIDULATORS

These are of iron. Under some conditions it is necessary that these shall be lead-lined or made of cast iron. They shall have a cone bottom. Weak acid is brought to these tanks from the weak acid tank through a lead pipe which discharges near the bottom. They are arranged so that either compressed air or steam can be admitted near the bottom of the tank.

These tanks discharge through a sight glass arranged with a three-way cock so that the tanks can discharge to the sewer or to the crude phenol tank.

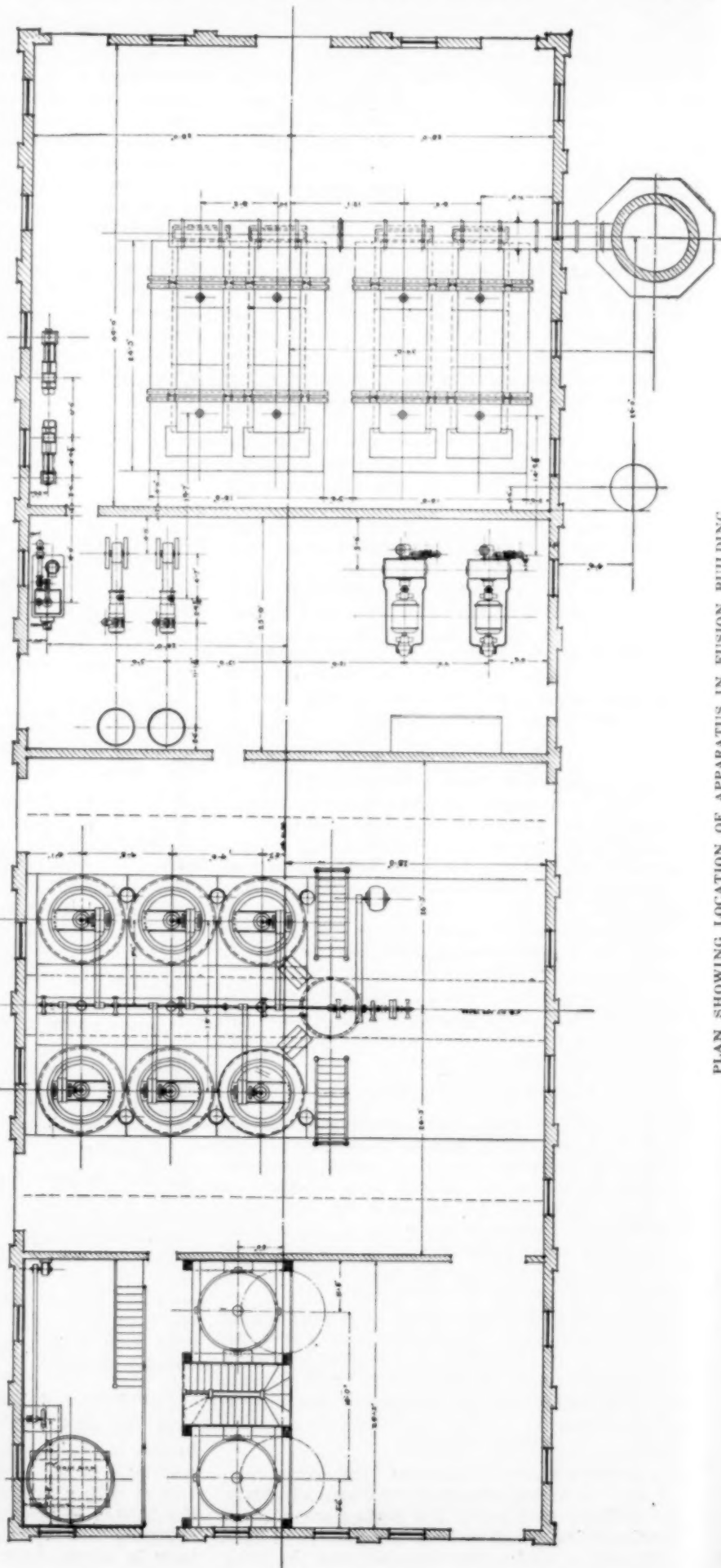
Between the separator and the sewer there should be a small tank arranged in the shape of a decanter so that in case any phenol is carried out with the waste solution it can be recovered from the top of this tank.

#### CRUDE PHENOL TANKS

These are sheet iron tanks provided with indirect steam-heating coils. These should be of sufficient capacity to hold three days' production of crude phenol. From the fusion kettles to the crude phenol tank, the apparatus is all in one building.

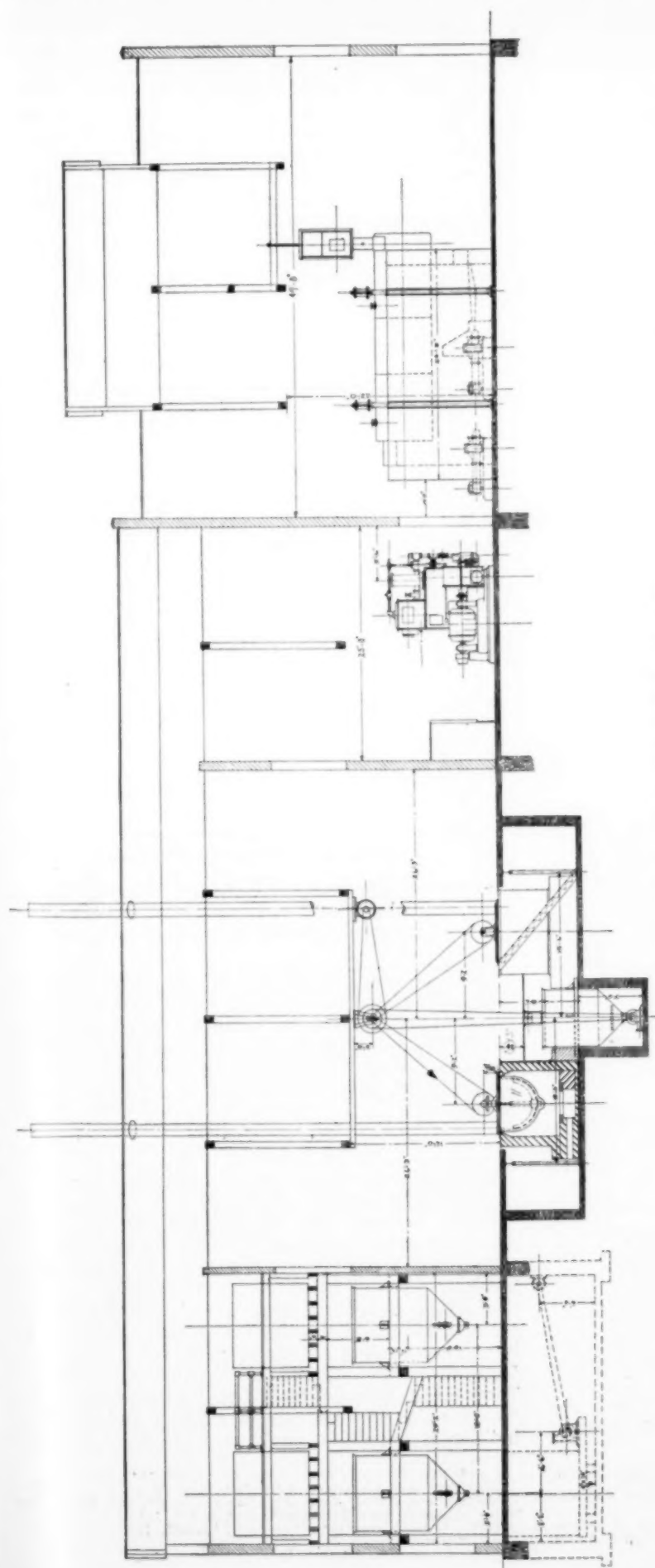
#### REFINING STILL

The refining still, which is located in the first-mentioned building, should be of column type with dephlegmator. The condenser should contain silver tubes and all portions of the condenser coming in contact with the finished phenol should be silver or silver-lined. The pipes



PLAN SHOWING LOCATION OF APPARATUS IN FUSION BUILDING





LONGITUDINAL SECTION OF FUSION BUILDING

from the condenser through the watch glass to the phenol tank should be silver-lined and the valves (flanged gate valves) extra heavily silver-plated. The phenol receiving tank should be enamel-lined and all valves and fittings in connection therewith should be silver or silver-plated.

Cooling water for the condenser, which, of course, is warm water, should circulate from the tank through the condenser, back through a cooler and into a storage tank. The cooler, which is similar to a tubular condenser, is piped with cold water which is so regulated that the temperature of the water in the phenol condenser can be held at a predetermined point. The apparatus in general should be liberally equipped with thermometers.

The phenol still is heated with indirect steam, large coils being used in the bottom of the still, which is a cylindrical tank, laid in a horizontal position. The manhole into this tank should be large enough so that the heating coils may be removed as a whole. This permits of a heating coil without joints. For a still of this type a wet vacuum pump is sufficient. The receiver for water fraction may be an iron tank. Finished phenol is drawn from the phenol receivers into the packages in which it is shipped.

#### POWER PLANT

Economy of fuel should be carefully considered. The following plan has been found to be very successful.

Engines or turbines exhausting against a back pressure of 15 lb. to the square inch; this 15-lb. exhaust line is carried through the sulfonating building and this steam is used in the evaporator to heat the storage tanks, etc., the condensed water from this system going to a hot-water tank.

The exhaust from all the pumps of every description and all compressors goes into a low-pressure exhaust line which goes to the hot-water heater, the feed-water heater and in winter to heat the building. The condensation from the heating system when in use goes to the hot-water tank.

There is a connection from the high-pressure steam lines through a reducing valve into the 15-lb. steam line in case the supply of steam to the 15-lb. line is insufficient. There is also a connection from the 15-lb. line through a reducing valve into the low-pressure line, in case there is an excess of steam in the 15-lb. line. There is a connection from the 15-lb. line to the low-pressure line through a reducing valve, in case the

supply of steam in the low-pressure line is insufficient and a connection from the low-pressure line to the boiler-feed water heater and to the atmosphere in case there is an excess of steam in the low-pressure line.

The boiler plant and the engine room, aside from the points mentioned, are of ordinary construction.

All machinery of the plant must be driven preferably by motors supplied with current from the generators which are driven by the turbines. Alternating current should be used to avoid any possibility of sparks which are common in direct-current motors.

In such a plant as this, the labor cost and fuel cost per pound of phenol is very low.

The best type of building construction is steel frame, brick walls, with a roof made of gypsum blocks.

The cost of a well-designed phenol plant to produce 10,000 lb. of phenol per day, brick and steel buildings, power plant, complete, is about \$200,000. A plant for making 20,000 lb. a day costs about \$250,000.

Moses, Pope & Messer,  
New York City.

### The Viscosity of a Thermolized Paraffin Base Oil

BY GUSTAV EGLOFF AND ROBERT J. MOORE

In the study of the thermal decomposition of hydrocarbon oils the physical constant of viscosity is of some significance. In this note the effect of temperature and rate of oil flow upon the viscosity of the thermolized oil has been studied.

The paraffine base oil used was subjected to temperatures ranging from 500 deg to 700 deg C. and rates of oil flow from 12 to 36 gal. per hour. The viscosity of the oils was determined by means of the usual method in oil technology the Standard Engler Viscometer.

#### Experimental Data

Table 1 and Fig. 1 give the experimental data on the viscosities of a paraffin base oil thermolized at varying temperatures and constant rate of oil flow of 16 gal. per hour.

Table 2 and Fig. 2 give the experimental data on the effect of rate of oil flow on the viscosity of a thermolized paraffin base oil at constant temperature of 600 deg. C.

TABLE 1.

THE VISCOSITIES OF A PARAFFIN BASE OIL THERMOLIZED AT VARYING TEMPERATURES AND CONSTANT RATE OF OIL FLOW OF SIXTEEN GALS. PER HOUR					
Temperature, deg. C.	500°	550°	600°	650°	700°
Viscosity Engler Deg.	1.104	1.151	1.245	1.094	1.055

TABLE 2.

THE EFFECT OF RATE ON THE VISCOSITY OF A THERMOLIZED PARAFFIN BASE OIL AT CONSTANT TEMPERATURE					
Rate, gallons per hour.	12	16	22	30	36
Viscosity Engler Deg.	1.330	1.245	0.906	1.151	1.161

#### Discussion of Data

In the thermal decomposition of a paraffin-base oil the viscosity of the oil increased with increase of temperature to a maximum and then decreased as the temperature increased within the limits of the experiments. In Table 1 the maximum viscosity is noted at 600 deg. C. of 1.245 and the minima of 1.104 at 500 deg. C. and 1.055 at 700 deg. C. The effect of rate upon the viscosity at constant temperature of 600 deg. C. gave a minimum of viscosity 0.906 at 22 gal. per hour, and maxima of 1.330 at 12 gal. per hour and 1.161 at 36 gal. per hour.

Fig. 1 gives a maximum point and two minima in the viscosity with change of temperature; while a change

in rate gives a minimum and two maxima in Fig. 2. Greater decomposition of the starting oil takes place as the temperature is increased. This is a common phenomenon of the cracking of oils.<sup>2</sup> The opposite is the case when the rate of oil flow is increased, which is equivalent to the time factor<sup>3</sup> in chemical reactions. As the oil is passed through a heated tube with increased rapidity as exemplified by changing the rate of oil flow from 12 to 36 gal. per hour, the changes taking place in the oil grow less and less until a rate is reached where no decomposition at all takes place. At

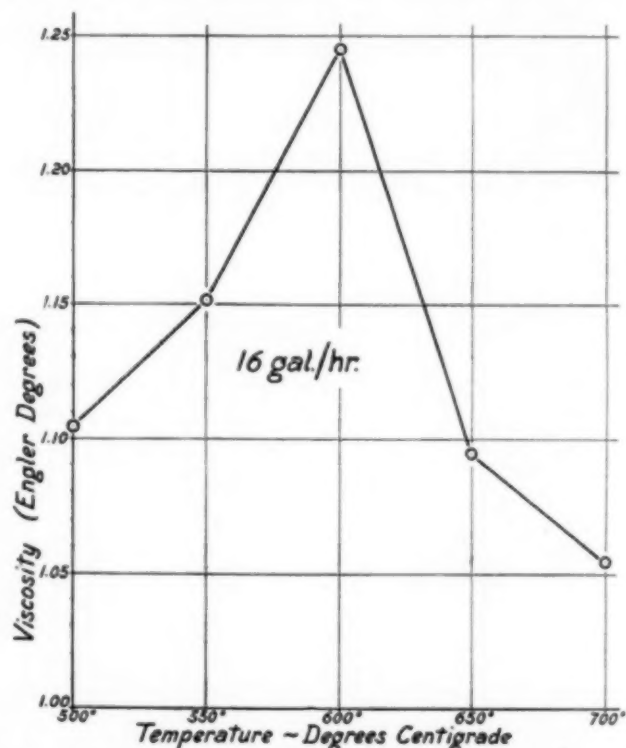


FIG. 1—VISCOSITY OF A PARAFFIN BASE OIL THERMOLIZED AT VARYING TEMPERATURES AND CONSTANT RATE OF FLOW OF 16 GAL. PER HOUR

12 gal. per hour and 600 deg. C. maximum decomposition of the starting oil took place with a resulting greater viscosity of the oil than the maximum temperature of 700 deg. C. and 16 gal. per hour gave. In short, the time factor in this series of experiments had a greater effect upon the viscosity than the temperature factor.

#### Theory

For mixtures of pure liquids the physical constant of viscosity is rarely a strictly additive property. The viscosity deviates from the additive law due to volumetric, thermal or molecular action between the constituents of the mixture. Perhaps this is due to the breaking down or building up of complexes in certain liquids due to surface tension<sup>4</sup> and viscosity relationships which would indicate that solution of one liquid in another is quite similar in character to thermal effects upon the solution. Wijkinder,<sup>5</sup> Lineberger,<sup>6</sup> Thorpe and Rodgers<sup>7</sup> have found experimentally that the viscosity of a mixture of miscible and chemically indifferent liquids is rarely if ever, under all condi-

<sup>2</sup>Egloff and Twomey, *Jour. Phys. Chem.* 20, 121, 1916.

<sup>3</sup>Whitaker and Alexander, *Jour. Ind. Eng. Chem.* 7, 484, 1915.

<sup>4</sup>Morgan and Egloff, *Jour. Am. Chem. Soc.* 38, 844, 1916. Ritt-

man and Egloff, *Jour. Ind. Chem. Eng.* 7, 578, 1915.

<sup>5</sup>Beibl, 3, 8, 1879; *Jour. Chem. Soc.* 71, 361, 1897.

<sup>6</sup>Amer. *Jour. Sci.* 11, 331, 1896.

<sup>7</sup>*Jour. Chem. Soc.* 71, 361, 1897.

<sup>8</sup>Holde, Examination of Hydrocarbon Oils. 1915. *Zeit. f. Angew. Chem.* 725, 1892; *Dingler's Polytech. Jour.*, 286, 210, 1892; *Chem. Ztg.*, 11, 1885.



tions a linear function of the composition of the mixture.

After thermal treatment the paraffin-base oil at 500 deg. C. was mainly composed of the paraffin and ethylene series of hydrocarbons with small amounts of aromatic compounds present. At 600 deg. C. the proportion of the aromatic series increased at the expense of the aliphatic hydrocarbons, while at the temperature of 700 deg. C. the thermolized oil contained mainly aromatic compounds of the benzene series. A satisfactory explanation of an increase of viscosity with increase of temperature and then a decrease as the temperature reached 700 deg. C. cannot be given as the complexity of the mixture of hydrocarbons is too great.

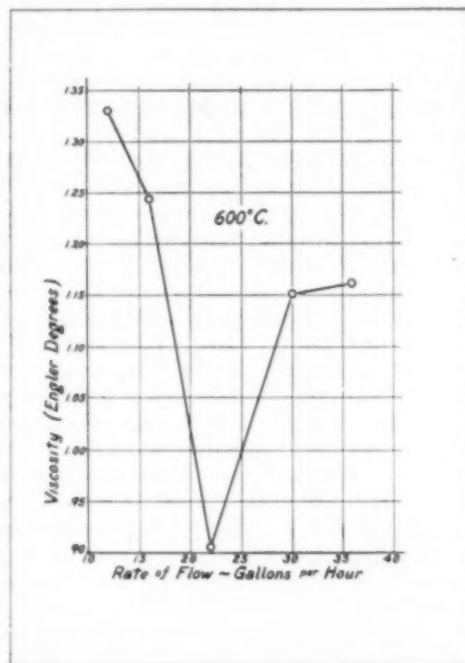


FIG. 2—EFFECT OF RATE OF FLOW ON THE VISCOSITY OF A THERMOLIZED PARAFFIN BASE OIL AT CONSTANT TEMPERATURE

From the data<sup>a</sup> of the viscosity of individual hydrocarbons of the paraffin, ethylene and benzene series some approximations may possibly be made as to the maxima and minima of the viscosities of the oils reported in this investigation. Dunsten and Thole in their book, "The Viscosity of Liquids," have shown that in homologous series there is an increase in viscosity corresponding to an increment of  $\text{CH}_2$ , but the increase tends to diminish as the molecular weight increases. Increase of carbon atoms in the molecule decreases the viscosity. Unsaturation increases the viscosity of the liquid. The viscosity of the benzene series is greater than the paraffin series.

As the temperature increases the viscosity of the treated oil increases which may in part be explained upon the basis of increased formation of the aromatic compounds of the benzene series and unsaturated hydrocarbons up to a definite temperature.\* As the decomposition reaction continues heterocyclic compounds are formed of naphthalene, anthracene and their methyl derivatives<sup>b</sup> and higher polycyclic hydrocarbons of which little is known. The greatly increased carbon content in the hydrocarbons of the latter type, one may infer from the work of Rellstab<sup>c</sup> indicated that

the viscosity decreases with increase of carbon content. The physical constant viscosity is an exceedingly complex phenomenon, however, and in view of the immense amount of work yet to be done upon the polycyclic hydrocarbons, the above theoretical considerations as applied to thermolized oils, are not inclusive.

#### Summary

1. A theoretical explanation has been given as to the phenomena of viscosity as applied to complex mixtures of aliphatic and aromatic hydrocarbons resulting from the thermal decomposition of a paraffin base oil.

2. The viscosities have been determined of a paraffin base oil thermolized at varying temperatures. The maximum in viscosity 1.245 was found to be at 600 deg. C. and constant rate of flow of 12 gals. per hour. The minima of 1.104 at 500 deg. C. and 1.055 at 700 deg. C. at the same rate are recorded.

3. The effect of the rate of oil flow upon the viscosity of a thermolized paraffin base oil has been determined. The minima in the viscosity was found to be 0.906 at 22 gal. per hour and maximas of 1.330 at 12 gal. per hour and 1.161 at 36 gal. per hour.

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Columbia University, New York City.

### Notes from the Palmer Physical Laboratory

BY E. F. NORTHRUP

#### Measurements of Resistivity and Thermal Electromotive Force of Samples of Calcium, Aluminium, Magnesium, Alloys of Aluminium and Magnesium and the Thermal E. M. F. Curve of Nickel vs. Nichrome

The writer is greatly indebted for the samples herein after known as Nos. 1 to 6 inclusive, to Dr. W. R. Whitney who presented them to him to be used for experimental purposes. He is also indebted to the Aluminum Company of America for the very pure sample of aluminium and its chemical analysis. The measurements of resistivity and a report on the results obtained were made by the writer's students, Mr. L. D. Howell and W. van B. Roberts. The data on the thermal e.m.f.'s were obtained and reported on by the writer's students, Mr. A. J. Mundt and Mr. B. S. McCutchen. The curve of the thermal e.m.f. of nickel vs. nichrome was obtained for the writer by Mr. L. A. Cavalcanti.

#### Resistivity Measurements

The measurements made were confined to the temperature range 20° to 150°C. Resistivity measurements were made on the following samples, all in the form of wires under 0.23 cm. in diameter:

- (1) was pure magnesium.
- (2) was 87.5% aluminium + 12.5% magnesium. Cold drawn.
- (3) was 10% aluminium + 90% magnesium.
- (4) was 90% aluminium + 10% magnesium. Cold drawn.
- (5) was 90% aluminium + 8% magnesium + 2% nickel. Cold drawn.
- (6) was pure calcium.
- (7) was 99.67% Al., 0.16% Si., 0.15% Fe., 0.02% Cu. and was annealed by heating red hot and cooling in air.

\*FOREWORD:—This is the first of a series of reports which the writer plans to give in the columns of METALLURGICAL AND CHEMICAL ENGINEERING of work done by the writer, and students and assistants working under his direction, at and with the facilities of the Palmer Physical Laboratory, Princeton, N. J.

<sup>a</sup>Landolt and Börnstein, Tabellon.

<sup>b</sup>Eglioff and Twomey, MET. AND CHEM. ENG. 14, 247, 1916.

<sup>c</sup>Eglioff, MET. AND CHEM. ENG. 15, Aug. 1, 1916.

<sup>d</sup>Rellstab, Diss. Bonn, 1868.

(8) was the same wire as (7) but not annealed by us.

#### APPARATUS USED

Kelvin double-bridge (Leeds and Northrup, catalogue number 4307).

Sensitive galvanometer (Leeds and Northrup, catalogue number 2280).

Wheatstone bridge.

Galvanometer (Leeds and Northrup portable type).

A German silver coil of about twenty ohms for heating.

A well aged copper coil used as a resistance thermometer of about 6.5 ohms and of about the same length as the samples.

Adjustable resistances, pan of oil, mercury thermometers, storage cells.

#### PROCEDURE

The resistance of the specimens was measured with a Kelvin double-bridge used with a Leeds and Northrup sensitive galvanometer. (Consult, *Methods of Measuring Electrical Resistance*, by E. F. Northrup. See, for general treatment of the Kelvin double-bridge, *arts.* 609-614, and for description of particular apparatus used, *arts.* 706, 1505.)

The specimens were held in a frame under suitable clamps. The potential point contacts were obtained with knife-edges held down with spring-pressure. The frame and sample were placed in a long narrow tank under kerosene oil. A thoroughly aged copper coil about 0.4 cm. in diameter and of about the same length as the distance between potential points, approximately 38 cms., was located close alongside the specimen. This coil, used as a resistance thermometer, served as the standard of temperature. The relation between its resistance and temperature was previously very accurately determined at the ice-point and the boiling-point of water. As the resistance-increase of copper with temperature in the temperature range 0° to 100°C. is strictly linear, the temperature of the coil, and hence the average temperature of the sample in close association with the coil, was very accurately determined from a resistance measurement of the coil. As an additional precaution against error in determining the temperature of the sample, the oil was stirred at the time a measurement was being made and all readings were taken when the temperature of the oil was nearly stationary.

The heating of the oil was effected by means of a heating coil of resistance wire immersed in it. As the oil cools slowly, when the heating current is turned off, a more rapid lowering of the temperature was occasionally obtained by adding cold oil to the tank. By stirring and adjusting the current through the heating coil it was not difficult to maintain the oil at nearly equilibrium temperature at the intervals at which measurements were made. A resistance coil, like the one described above, is very superior to a thermocouple, resistance-thermometer or other device which gives the temperature at a point. The reason is that the resistance-thermometer coil being of the same length as the distance between the potential points of the sample being measured gives the mean temperature of the sample between potential points, and, if the sample has a nearly constant temperature coefficient, inequalities in the temperature of the oil or the sample between the potential points introduce no error; for it can be considered that the resistance of the coil gives a mean temperature and since the variation of temperature along the length of the coil and sample is the same, the resistance of the sample is its resistance at the temperature deduced from the coil. This is strictly true when the resistance of both the copper coil and the

sample are linear functions of the temperature or if they are similar curves.

To obtain the temperature from the resistance of the coil we referred to a large chart on which the resistance of the coil had been plotted against temperature. The temperature readings were also occasionally verified by using a mercury thermometer carefully corrected and reading to tenths of a degree and hundredths by estimation.

The resistivity of a sample was calculated from the measured resistance. For this calculation it was necessary to measure the length between the potential points and the diameter of the sample. Diameters were obtained by taking the mean of numerous readings of diameter made with a Brown & Sharpe micrometer calipers at various points along the wire and various points around it.

The sensitivity of the measuring outfit was such that a relative error of more than one unit in the last place of decimals would become quite evident. Following a common practise of the writer the Kelvin double-bridge measurements were several times checked during the investigation by transferring without other change in the set up, the current and potential leads to a low-resistance standard known to be correct. When the outfit measured this standard correctly assurance was given that the measurements of resistance were being correctly made.

It seems certain, therefore, that, when measurements on a sample were several times repeated, the sample in the meantime having been heated or cooled between the different measurements, and the resistivity at a given temperature was found to vary (in some cases as much as 2 per cent) this variation cannot be due to errors of measurement. Rather it is shown by the measurements that within rather narrow limits the resistivity of several of the samples depends not only upon the temperature but also upon the previous thermal history of the sample; that is, whether before the measurement it has been heated or cooled and how fast. Slow cooling seems to leave the resistivity slightly diminished.

The absolute values of the resistivities are not only dependent upon the heat treatment of the sample, but are subject to an error in determination which may amount to as much as one-half to two per cent resulting from the difficulty of accurately estimating the cross-section of the samples from micrometer readings of the diameters of the wire. All relative values are certainly correct to within 0.2 per cent.

#### DATA AND RESULTS

The data used for deducing resistivity from resistance is given in the table below:

DATA FOR DEDUCING RESISTIVITY FROM RESISTANCE

Sample	Length Between Pot. Pts. in Cms.	Mean Diameter in Cm.	Mean Section in Sq. Cms.	k=Section/Length = Resistivity Divided by Resistance = $\rho/L$	Probable per Cent Error in k and Hence in $\rho$ (Estimated)
(1).....	32.9	.102	.00817	.0002482	2
(2).....	38.2	.1064	.00889	.0002327	2
(3).....	38.82	.1069	.00800	.000206	1
(4).....	38.83	.10503	.00866	.000223	0.4
(5).....	38.2	.08138	.0052	.0001362	0.4
(6).....	22.3	.12165	.01162	.00521	0.4
(7).....	38.9	.2254	.0399	.001025	1.0
(8).....	35.4	.2254	.0399	.00111	.....

The sample of calcium wire (sample No. 6) is (according to a statement made to the writer by Dr. Whitney) taken from a lot made by the Research Laboratory of the General Electric Co. which is probably the first wire ever drawn of pure calcium. No analysis was supplied to the writer but the wire was stated to be of pure calcium. If exposed to damp air it oxidizes slowly



superficially and the sample was preserved under paraffin. The oxidization is not, however, too rapid to prevent the wire from being handled for purposes of micrometering it. It was, of course, under oil while the measurement was being made. The resistivity of this sample was 5.32 microhms at 20°C. and 6.64 microhms at 100°C. per cm<sup>2</sup>. This resistivity of calcium is therefore but slightly greater than pure magnesium which for the sample tested was 4.75 microhms per cm<sup>2</sup> at 20°.

It was found that although aluminium and magnesium both have low resistivity their alloys have a considerably higher resistivity than either of the constituents and that increasing the proportion of magnesium greatly increases the resulting resistivity. Thus, at 20°C. sample No. 4 consisting of 90 Al. + 10 Mg. has a resistivity of 8.28 microhms, while sample No. 3, consisting of 10 Al. + 90 Mg. at the same temperature has more than twice the resistivity, 19.18 microhms per cm<sup>2</sup>.

The curve sheet, Fig. 1, embodies the results obtained in the measurements and will be understood without further comment. However, as the resistivity varied with repeated heatings and coolings, another curve, No. 2, is given which shows the striking manner in which this change in resistivity occurs in the case of the alloy 90 Mg. + 10 Al., namely, sample No. 3. The occurrence of this phenomenon happened to some extent with all the samples and it took a very long time to conduct the many series of measurements required to satisfy ourselves that the resistivity of the samples was really changing and that the measurements were in no wise in error.

As the writer has stated in previous communications many metals and most alloys when in the solid state

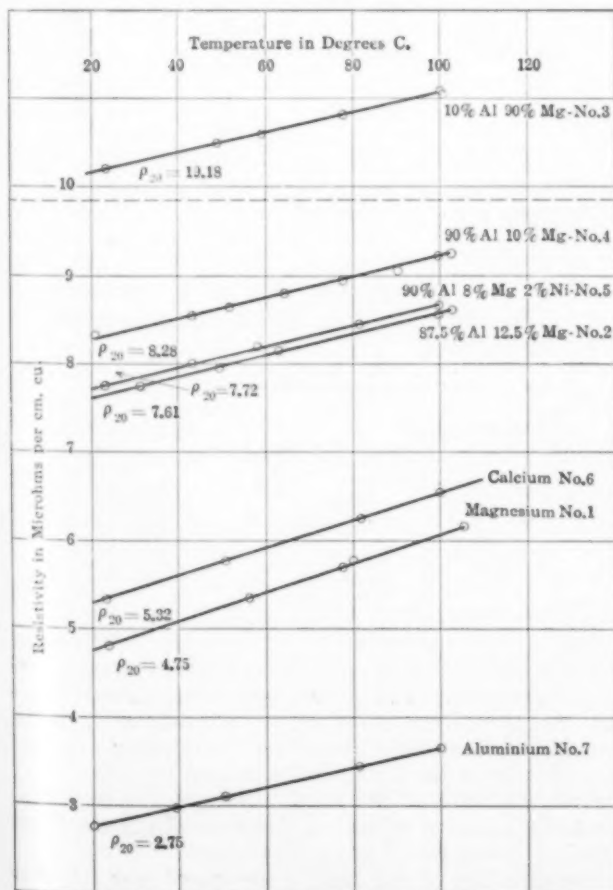


FIG. 1—CURVES OF RESISTIVITY AS FUNCTION OF TEMPERATURE

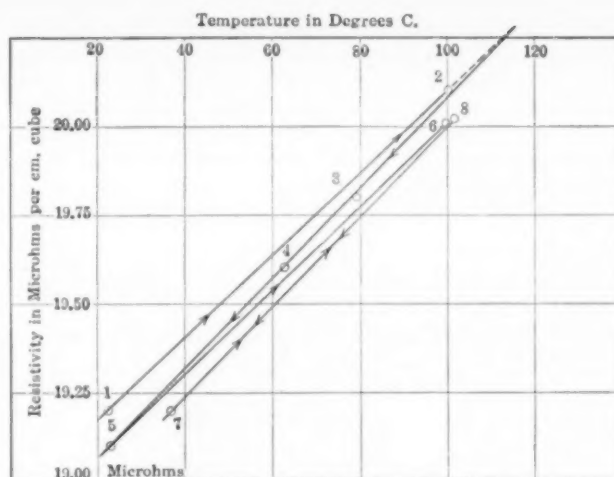


FIG. 2—RESISTIVITY OF ALLOY 90 PER CENT Mg. AND 10 PER CENT Al.

Points 1 to 2, slow heating; 2 to 5, slow cooling; 5 to 6, slow heating; 6 to 7, slow cooling; 6 to 8 heated by removing cold oil and pouring in hot oil. It will be noted that the last curve up is identical with the previous one down.

will have a resistivity which is more or less dependent upon past physical history, and if, therefore, we wish to obtain resistivity measurements for samples which have a resistivity dependent only upon temperature and chemical composition, we must bring the samples into the molten state. (See numerous articles by the writer in the *Journal of the Franklin Institute*, beginning in February, 1913.) In the case, however, of a very pure metal as copper, platinum or nickel which has been drawn into wire and then thoroughly "aged" by prolonged heating, the resistivity will become a function of the temperature only, if the temperature is maintained below that at which the sample was aged. If this were not so pure metals could not be relied upon as satisfactory pyrometric substances for use in resistance thermometry.

#### Determinations of Thermal Electromotive Force

The object sought in the series of measurements described below was to determine the thermal e.m.f. at various temperatures developed in a thermocouple made from the General Electric Company's samples Nos. 1 to 6 as described above, also the sample of aluminium, No. 7, all against pure copper; and an additional series of measurements were thought to be desirable on the combination *pure nickel vs nichrome*, for reasons which will appear later.

Arrangements were made so that all readings of e.m.f. would be given to the units place in microvolts. With the exception of the nickel vs. nichrome combination, which was studied in a slightly different manner, the following procedure was adopted:

**The method of measurement.**—Accurate temperature points were obtained by making use of the following fixed points: The boiling-point of water, the freezing-point of tin, and the freezing point of zinc. The e.m.f.'s of the various samples developed at these points when the cold junctions of the couples were in an ice-bath were read with a potentiometer. The apparatus employed consisted of a Leeds and Northrup potentiometer and galvanometers, a Weston standard cadmium cell, a small electric furnace wound with nichrome ribbon, a small Dewar flask filled with cracked ice, a hypsometer and some small accessories. The electrical connections employed are shown in the diagram Fig. 3.

The first step was to construct thermocouples using the various samples against Cu. The details of construction are sufficiently shown in Fig. 3. A is a small

quartz tube, and B is a protecting tube of Marquardt ware. It was found impossible to weld the junctions and hence a mechanical connection was resorted to. This was made by flattening the ends of the wires and wrapping them with fine Cu. wire. The apparatus was set up as shown in Fig. 3 for obtaining the melting points of metals and the hot junction was placed in the hypsometer for the 100° point.

The e.m.f.'s generated were read, while steam was

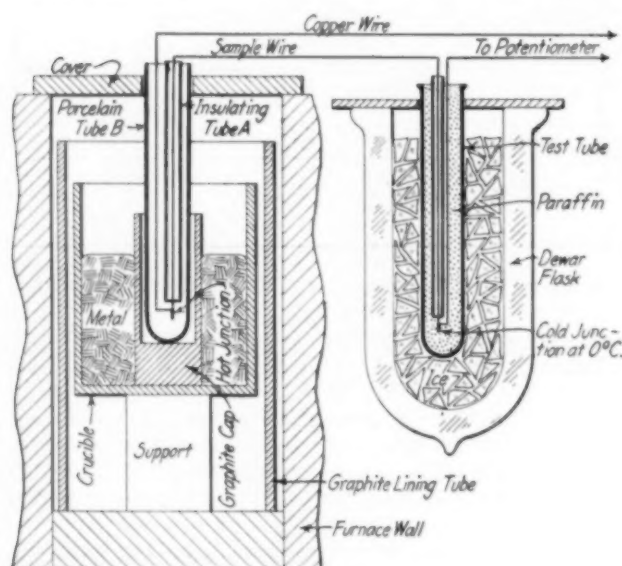


FIG. 3—EXPERIMENTAL ARRANGEMENT

pouring out freely. The barometer was read and the correction for boiling-point found. Six readings were taken and the average value used. The other junction during these experiments was kept at zero degrees Centigrade by being placed in the Dewar flask filled with cracked ice.

The tin-point and zinc-point were obtained as follows: The metal was placed in an alundum thimble which was located in a small, vertical, nichrome-wound tubular furnace. The inner wall of the heating tube was lined with a graphite tube so that when the furnace was heated above a red heat a reducing atmosphere would be developed. This is desirable and, in fact, necessary, when one is obtaining the copper-point, to preserve the metal free from oxidation on its surface.

The hot junction of the couple was slipped into a small tube of Marquardt and this in turn was slipped into a very thin-walled graphite tube closed at the bottom end. The hot junction thus protected was immersed in the molten metal.

The heating current of the furnace was either shut off or reduced and readings of e.m.f. were made on the potentiometer at frequent intervals as the metal cooled. As is well known the temperature of the metal holds stationary while solidification is occurring and the e.m.f. of the couple read at this time is the e.m.f. which it develops at the temperature at which the metal freezes. Both in the case when obtaining the tin-point and the zinc-point the metal was heated and allowed to cool until quite solid and then again heated and again allowed to cool, this being repeated at least four or five times. The successive readings of the e.m.f. taken at the freezing-point of the metal were found to agree almost exactly.

The method described above was followed for all samples except No. 6 (pure calcium) for which the following procedure was adopted. The hot junction was placed in a kerosene bath which was heated electrically, the cold junction being maintained at zero degrees Cen-

tigrade in the Dewar flask. The temperature was read by means of a resistance thermometer, all points being determined while the oil-bath was cooling and after it had been well stirred. For points above 100°C. the hot junction was placed in a protecting tube filled with Crisco, which stands a much higher temperature than oil. A mercury thermometer was bound to this tube and the unit so made was placed in the furnace.

Tables I and II of data obtained on sample No. 4 (90 Al + 10 Mg vs Cu) and sample No. 6 (Ca vs Cu) will explain the manner of taking the readings and the general character of the results obtained:

TABLE I—DATA SHEET OF SAMPLE NO. 4

Barometer reading, 77.13 cm.	E.m.f.'s at boiling point of water in microvolts.
Corrected boiling point, 100.4.	228
	227
	228
	227
	225
	222
	226.2 aver.

FREEZING POINT OF TIN		FREEZING POINT OF ZINC	
Time	E. m. f.	Time	E. m. f. Microvolts
3:13	1003	5:08	2268
:14	1087	:09	2310
:15	1077	:10	2240
:16	1041	:12	2173
:17	1007	:13	2084
:18	948	:14	1997
:19	884	:15	1929
:20	843	:16	1837
:21	807	:17	1776
:22	754	:18	1691
:23	736	:19	1645
:24	692	:20	1598
:25	692	:21	1598
:26	692	:22	1598
:27	692	:23	1598
:28	692	:24	1598
:29	692	:25	1598
:30	692	:26	1598
:31	692	:27	1598
:32	687	:28	1598
:23	677	:29	1582
		:30	1483

Freezing point of tin, 231.9 degrees C.\*  
E. m. f. at tin point, 692 microvolts.  
Freezing point of zinc, 419.4 degrees C.\*  
E. m. f. at zinc point, 1598 microvolts.

\*Geophysical laboratory values.

TABLE II. DATA SHEET ON SAMPLE NO. 6, CALCIUM WIRE.

The following points were determined with the sample under kerosene oil:

TABLE II—DATA SHEET ON SAMPLE NO. 6, CALCIUM WIRE

Temperature in Degrees C.	E. m. f.'s in Microvolts
24	218
51.2	514
56	558
89	940
90.4	968
92	1000
96	1027

The curve for calcium (Fig. 4) was plotted from the above results. An attempt was made to observe the e.m.f.'s developed up to 335 degrees, using Crisco to protect the wire from oxidation. No consistent results, however, were obtained due to the occurrence of frequent open circuits at the hot junction caused by oxidation of the calcium wire at the joint. The point indicated as the freezing point of tin on the Summary Data Sheet (Table II) was found by extrapolation.

The direction of the e.m.f.'s generated was found to be through the hot-junction from the sample to the Cu. in every case.



The results contained in the following table are all plotted in curves Fig. 4.

TABLE III—SUMMARY OF DATA OBTAINED

	Freezing Pint of Water	E.m.f.s. generated at Boiling Pint of Water	Freezing Pint of Tin	Freezing Pint of Zinc
No. 1.....	0	301	810	1737
No. 2.....	0	245	682	1555
No. 3.....	0	599	1374	2862
No. 4.....	0	226	692	1598
No. 5.....	0	255	703	1635
No. 6.....	0	1080	3080*	.....
No. 7.....	0	372	930	2934

\*See special data sheet on this sample.

The curve, Fig. 5, for the thermal e.m.f. of very pure nickel vs nichrome (made by Driver-Harris Co.) was obtained for the writer by Mr. L. A. Cavalcanti and is interesting from two standpoints. First it gives results obtained by a well-known method which may be used with great ease by any one for very accurately calibrating a thermocouple up to the temperature of freezing copper ( $1082^{\circ}\text{C}$ .), no use being made of any instrument, thermocouple or resistance thermometer to serve as a standard of temperature.

The method gives with great simplicity five accurate points for tracing a curve, which number is quite sufficient for ordinary purposes. The method is quite similar to the one, just described, which was used in determining the thermal e.m.f.s. of the different General Electric Co.'s samples.

A small nichrome-wound furnace arranged to stand vertical, with a chamber large enough to hold a crucible of graphite one inch in diameter and about three inches high, serves admirably the purpose of a heat-producing apparatus. The bottom of the furnace-heating tube should be tightly closed and the thermocouple tube should be passed through a small hole in the cover of the furnace, which should fit tightly (see Fig. 3). The graphite of the crucible, immediately a red heat is obtained, converts the atmosphere in the furnace chamber into a reducing atmosphere which preserves the surface of the metals (Sn, Zn, Sb and Cu used for giving fixed points of temperature), free from oxidation.

A crucible should be provided for each metal employed and each crucible about two-thirds filled with a partic-

ular metal, may be used over and over again, and so serve the purpose of giving a fixed-point of temperature for many thermocouple-calibrations.

There should also be provided as many graphite tubes (closed at the bottom and with a wall less than a mm. thick), as there are metals used. These graphite tubes serve as a cap (see Fig. 3) which fits over the end of a

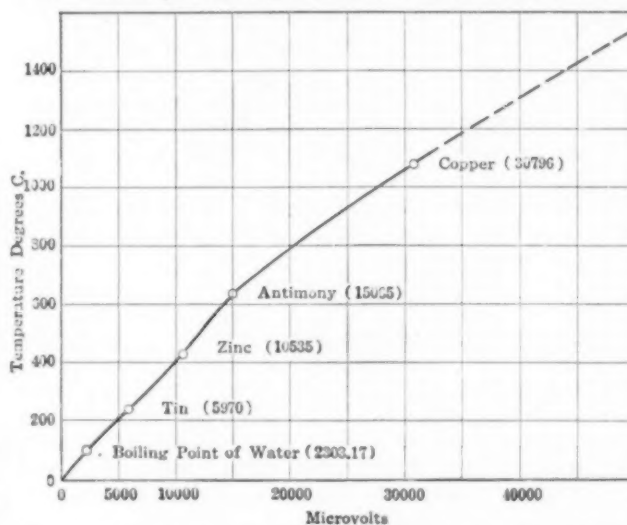


FIG. 5—THERMAL E.M.F. CURVE FOR NICHROME VERSUS NICKEL THERMOCOUPLE

thermocouple, loosely. This cap will prevent any undue strain being exerted on the casing of the thermocouple when the metal, in which the thermocouple is immersed, freezes and contracts and the thermocouple may be removed from the crucible containing the solidified metal without reheating.

It was with this method, as just described, that each of the points, except the boiling point of water, was obtained for plotting the curve shown in Fig. 5. The e.m.f. was, of course, read with a potentiometer at the time a metal was in the process of freezing, and the temperature and e.m.f., consequently, remained for a certain interval constant.

The curve, Fig. 5 is, secondly, very interesting because it shows that there is an interval of temperature (between  $350^{\circ}$  and  $500^{\circ}\text{C}$ .) in which the curve makes a slight inflection, the e.m.f. not increasing in the regular way with increase in temperature that it does outside this interval. This is probably due to the fact that nickel has a recalcence point in the neighborhood of  $360^{\circ}\text{C}$ . As a combination of any of the metals of the iron group with nichrome give a high thermal e.m.f., and as all these metals have high melting-points they would naturally be considered very useful as one metal in a combination for a base-metal thermocouple. The fact, however, that the curve shows a change in its regular course near a recalcence point of a metal belonging to the iron group, should at least put one on his guard against too implicit reliance on the accuracy of the temperature indications of a thermocouple in which nickel or nichrome forms one element, in the neighborhood of the temperature of recalcence. This change in the course of the curve may not exist in the combination cobalt vs. nichrome; but should be looked for very carefully.

In the combination nickel vs. nichrome the e.m.f. acts to send current from nickel to nichrome through the hot junction.

The experimental work described above was done between January and March, 1916.

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Princeton, N. J.

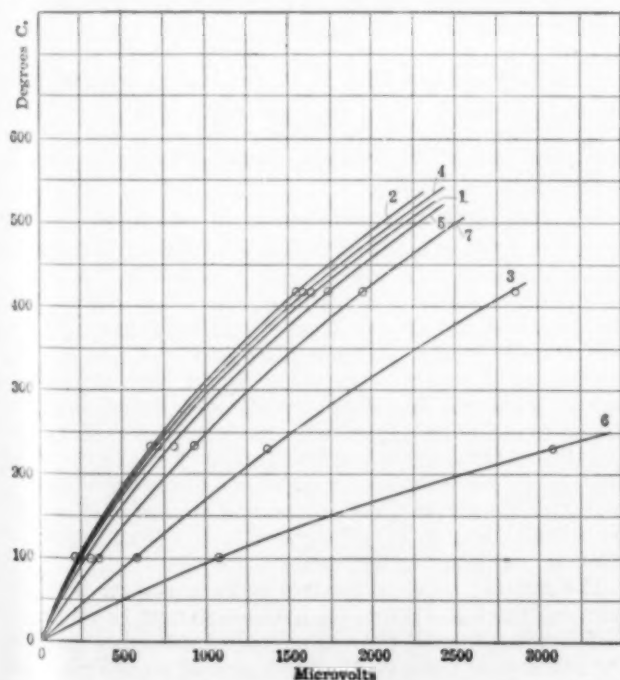


FIG. 4—CURVES OF THERMAL E.M.F.S.

## The Principles of Filtration

BY D. R. SPERRY

Filtration consists of the process of separating the solids from a mixture of solids and liquid by causing the liquid to flow away from the solids through a porous mass the openings of which are too small to allow passage of the solids.

The porous mass is called the filtering medium and is composed of two parts: that which was provided in order that filtration might begin, called the filter base, and that which was formed during filtration, called cake, consisting of the solids which were too large to pass through the openings of the porous mass.

The mixture of solids and liquid is called the mixture, while the liquid which was separated from the mixture is called the filtrate.

### THREE INDISPENSABLE CONDITIONS OF FILTRATION

There are three indispensable conditions of filtration:

1. There must be a difference of pressure between the two faces of the porous mass, the higher pressure being on the side in contact with the mixture. The intensity of this pressure difference must be great enough to cause the liquid to flow through the porous mass. Without this pressure there would be no flow through the filtering medium, and hence no filtration.

2. There must be a filter base. If there is no filter base, there is no porous mass with which to start filtration, and therefore no filtration at all. In practice the filter base often consists of cloth or paper.

3. There must be a filter. A filter consists of a device employed to support the filter base and to confine the mixture so that the same may be placed under pressure and in contact with the filter base.

Inasmuch as there is a difference in pressure between the two sides of the filtering medium it follows that the low-pressure side must be supported. If this is not done the filter base will not remain in place and filtration will not result. Also, if the mixture is not held in place on the filter base it will flow away and filtration will not take place. A filter is therefore indispensable.

### FILTRATION IN DETAIL

In order more clearly to comprehend the process of filtration, Fig. 1 is presented.

At A a mixture is shown in a confined space and in contact with a filter base X. Directly below is shown a receptacle to catch the filtrate. At the instant shown, filtration is at the very point of starting. Here can be observed the importance of the filter base, for at this step it comprises the entire filtering medium. At no other point in the process of filtration is this true. It initiates filtration, supplying for the time being the porous mass which later will be composed mostly of solids from the mixture.

At B flow of the liquid through the porous mass has proceeded for a certain length of time. The liquid or filtrate has collected in the receptacle below, while the

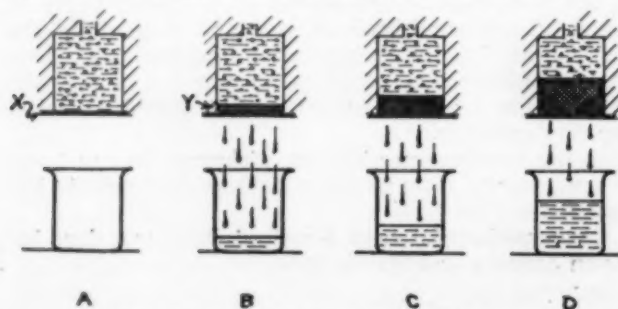


FIG. 1—FOUR STAGES OF FILTRATION

solids, unable to pass through the porous mass with the liquid, are necessarily left as a deposit Y upon the filter base. The filtering medium now no longer consists of the filter base only, but of two parts, the filter base plus the deposited solids or cake. It should be observed that the liquid now has to pass through a porous mass of greater thickness than in the case at A; consequently, assuming the pressure of the mixture to be constant, its rate of flow will be decreased.

At C an interval of time has elapsed from the state at B sufficient to double the amount of filtrate caught in the receptacle. As a result, assuming that equal quantities of liquid carry equal amounts of solids, the thickness of cake is twice that found at B. Since the liquid must flow through this greater depth of porous mass, its rate of flow is necessarily much less at C than it was at B.

At D still another interval of time has passed—enough so that the filtrate in the receptacle is twice that found at C. This doubles the thickness of cake over that found at C, resulting in a further decrease in the rate of flow of the liquid.

### TWO PROCESSES AT WORK

A careful study of Fig. 2, in the light of the details

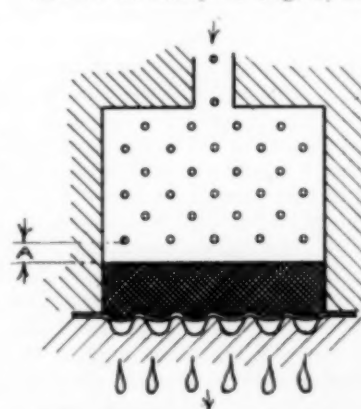


FIG. 2—CONDITIONS DURING ONE INSTANT OF FILTRATION

just given, will disclose the fact that there are two distinct and constantly changing processes going on, as follows: (1) Flow of liquid through porous mass; (2) building up of the porous mass or cake. These two processes are constantly changing because the liquid as it flows into the cake is continually leaving its solids behind, thus constantly increasing the thickness of the

porous mass, while simultaneously with this action the liquid is continually decreasing its own rate of flow, due to the increasing thickness of solids through which it has to pass.

It is now evident that if an expression showing the relation between these two processes can be devised and the laws of each are determined, the two can be combined in a known relation, thus deriving the fundamental laws of filtration.

### RELATION BETWEEN THE TWO PROCESSES

In Fig. 2 is illustrated a cross-section of a filter in which the process of filtration is proceeding. A study of the instantaneous conditions there depicted reveals the fact that the rate of flow of the liquid through the porous mass is, at that moment, equal to the rate of flow which would obtain were there liquid only above the same. This can be best comprehended by considering the layer of liquid A, for it can readily be seen that during the instant this layer is entering the cake the conditions are the same as though liquid only were above. In actual conditions, of course, the particles of solids are not liable to be equally spaced in the liquid, but the effect in principle is the same.

The relation between the two processes—flow through cake and thickness of porous mass—can now be set down as follows: Rate of flow at any instant = rate of flow for liquid only through the thickness of porous mass at that instant.

The relation between the two processes being now



established, the next step is to investigate separately the laws governing each, and then by means of the common relation combine the two sets of laws to form the fundamental laws of filtration.

#### The First Process—Rate of Flow Through the Porous Mass

To investigate the laws governing the flow of liquids through a porous mass, the apparatus shown in Figs. 3 and 4 was employed. The method consisted in actually depositing a cake by the process of filtration upon a suitable filter base, and then measuring the rate of flow through the cake under various pressures with clear liquid only.

The apparatus consists of a small filter press having one plate and frame, the filter base being in a horizontal plane. This latter was done in order to minimize the effects of sedimentation as much as possible in order to secure a cake of uniform thickness. At the beginning of the test a piece of No. 10 duck *E* was laid upon the filter plate *F*. Upon the duck was placed frame *D*, while upon *D* was placed the head *C*, with a thin packing between them. Pressure was then applied mechanically so as to squeeze the pieces together. The pipe connection on the head was piped to a hand pump *A* on one side, and to a general water system *B* on the other. Valves were placed so that feed could be obtained from either source.

In the mixture tank were placed 3 quarts of water and  $1\frac{1}{8}$  ounces of kieselguhr.\* This material was selected because the particles of which it is composed are insoluble in water and quite rigid, thus avoiding errors due to leaching effects or change in shape of the solids.

After thoroughly agitating the mixture it was pumped into the filter chamber at 60 lb. per square inch pressure. This pressure was continued until about 1 quart of filtrate was obtained. At this point pumping was discontinued and the valve leading to the general water system was cracked just enough to keep the pressure constant at 60 lb. per square inch. The valve leading to the pump was then closed, and in order to assure complete deposition of the solids which were still in suspension within the frame, water was allowed to run from the filter until about three-fourths of a quart had escaped. The rate of flow was then measured, the gage showing 60 lb. per square inch.

Next the valve to the general system was closed just enough to show 50 lb. per square inch on the gage. The rate of flow was then measured. This process was kept on in decrements of 10 lb. per square inch until 10 lb. per square inch was reached, at which point the valve was closed entirely, the head removed and the approximate thickness of cake measured. Temperature was maintained at constant value throughout the test. The data obtained are given in Table I.

\*A typical analysis of the Kieselguhr as used is given by the producers thereof as silica,  $\text{SiO}_2$ , 89.17 per cent; alumina,  $\text{Al}_2\text{O}_3$ , 1.85; iron oxide,  $\text{FeO}$ , 0.64; titanium oxide,  $\text{TiO}_2$ , 0.03; lime,  $\text{CaO}$ , 0.54; magnesia,  $\text{MgO}$ , 0.52; loss on ignition, 5.64.

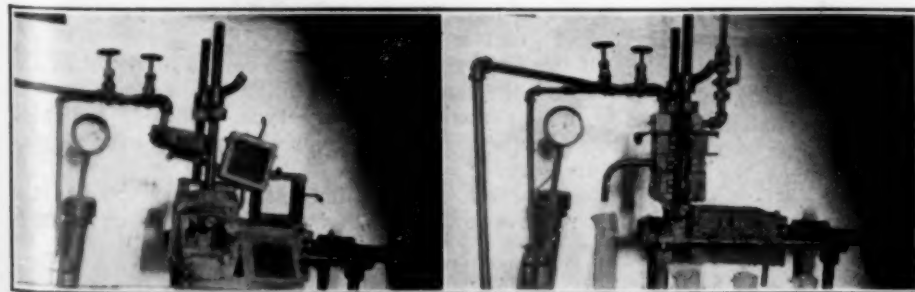


FIG. 4—VIEW OF FILTER, OPEN ON LEFT, CLOSED ON RIGHT

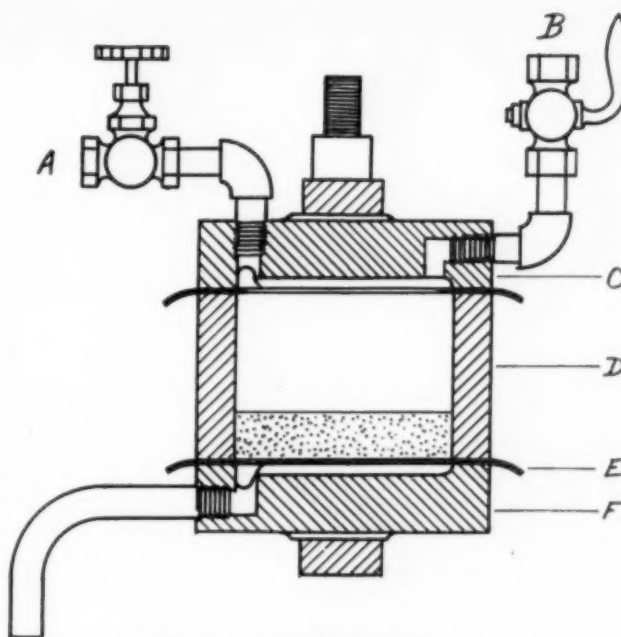


FIG. 3—EXPERIMENTAL FILTER PRESS

TABLE I

Date of test, March 29, 1915.  
Place of test, Basement Laboratory, 178 Union Avenue, Batavia, Ill.  
Temperature, about 65 deg. Fahr.  
Filter base, No. 10 duck.  
Mixture,  $1\frac{1}{8}$  ounces of kieselguhr in 3 quarts of water.  
Filtering area,  $1/20$  sq. ft.  
Apparatus, as shown in Figs. 3 and 4.  
Pump,  $1\frac{1}{2}$ -in. x 3-in. stroke, single-acting, hand-operated.

#### Method of Procedure:

- (13) From 5:16 p. m. to 5:18 p. m. pumped mixture in filter at 60 lb. per square inch until 1 quart of filtrate was obtained.
- (2) Opened valve to water system at 60 lb. per square inch and closed valve on pump line.
- (3) Allowed water to flow from filter until about 12 ounces was collected.
- (4) Regulated pressure by cracking water valve and made reading as follows:

Water Pressure	Time of Reading, P. M.	Flow of Water, Fluid Ounces	Rate of Flow in Cu. Ft. Per Hr.
60	5.22 to 5.25	26	4.06
50	5.26 to 5.29	21	3.28
40	5.30 to 5.33	17	2.66
30	5.34 to 5.37	12.5	1.95
20	5.38 to 5.41	8.5	1.33
10	5.43 to 5.46	4.2	.656

#### Remarks

Cake found to be about  $\frac{1}{2}$  in. thick.

Cloth showed grooving or deformation apparently the same as observed at conclusion of tests made with ascending pressure increments.

Cake showed very faint coloration on surface in contact with water only.

The plotted results from the test are shown in Fig. 5.

Perhaps the most interesting result of this test is the fact that it shows that the rate of flow of the liquid through the cake varies as the first power of the pressure.

So straight a curve was not obtained, however, at the

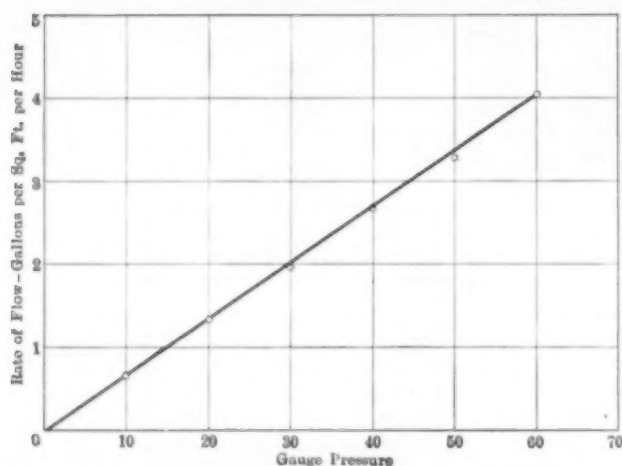


FIG. 5—EFFECT OF PRESSURE ON RATE OF FLOW OF WATER THROUGH FILTER CAKE OF KIESELGUHR

first trial. In previous tests the rates of flow were measured in ascending instead of descending increments. Under these conditions it was quite impossible to secure a straight-line curve. Careful examination of the cakes disclosed the fact that this was due to the drawing away of the edges of the cake from the sides of the frame due to the deformation of the filter cloth with the increasing pressure. This condition resulted in the exposure of an abnormal surface and the development of shorter porous paths to carry away the liquid. This caused the curve to bend upwards with increasing pressure.

A slight brownish coloring left by the liquid as it entered the cake showed conclusively that it gained entrance on the sides as well as top. A study of the cloths at the finish of ascending and descending tests, the maximum pressure being the same in both cases, showed a deformation or ridging the same in each instance. This would indicate that once a filter cloth is deformed by pressure the deformation becomes permanent. Examination of descending test cakes showed a brownish coloring on the top only, indicating that the liquid did not enter the cake at the sides.

#### FLOW THROUGH FILTER CAKE A CAPILLARY PHENOMENON

To many the fact that the rate of flow through a filter cake varies as the first power of the pressure will be looked upon as rather singular. Most would expect the rate of flow to vary as the square root of the pressure according to the law of falling bodies and the various flow-through-pipes formulas found in works of hydraulics and in handbooks.

It has long been known, however, that there are two distinct kinds of flows of liquids through tubes, namely, sinuous and non-sinuous. The first has been also called eddying, while the second has been called eddyless, parallel, direct or capillary flow.

If water under very calm conditions is caused to flow through a smooth tube with flared inlet at very low pressure, and then the pressure is very gradually increased, the flow for a time through the tube is very smooth and even, the rate of flow varying as the first power of the pressure. It has been shown that during this period the liquid flows in parallel lines without eddies or sinuosities. This has been shown by the injection of coloring matter in the liquid while flowing through a transparent tube.

As the pressure increases a point is finally reached in which quite suddenly the rate of flow commences to vary as the square root of the pressure, and simultaneously with this event the flow of the liquid is shown to break up into smoky convolutions caused by eddies and

sinuosities. This point is called the critical point, and marks the moment of change from one type of flow to the other.

The cause of the difference in behavior of the flow in respect to pressure is said to be due to the fact that in the non-sinuous flow the chief resistance to flow is caused by the viscosity of the liquid, while in the sinuous flow the chief resistance is that due to friction between the liquid and the walls of the tube. These two types of liquid flow were very beautifully pointed out and explained in 1883 by Prof. Osborne Reynolds, F.R.S., in a paper entitled "An Investigation of the Circumstances Which Determine Whether Motion of Water Shall Be Direct or Sinuous, and of the Law of Resistance in Parallel Channels." This paper is well worth reading, and there will be found therein a logarithmic homologue of the "pressure-rate of flow" curve through a tube. The critical point is very interestingly indicated by the point at which the slope changes from 1 to 0.5.

A later paper on this same subject<sup>2</sup> by Professor Coker and Mr. Clement, 1903, communicated by Prof. Osborne Reynolds, F.R.S., entitled "An Experimental Determination of the Variation with Temperature of the Critical Velocity of Flow of Water in Pipes," is also of much interest.

Poiseuille,<sup>3</sup> in 1842, developed from experimental data an empirical formula for sinuous or eddyless flow as follows:

$$v = \frac{\pi p r^4}{8 l u}$$

Where  $p$  = pressure,  $r$  = inside radius of tube,  $l$  = length of tube,  $v$  = vel. of flow,  $u$  = coefficient of viscosity.

Later this empirical formula was derived by purely theoretical considerations.<sup>4</sup>

The coefficient of viscosity varies with the temperature. Poiseuille shows the general relation to be as follows:

$$N_t = \frac{N_o}{(1 + \alpha t + \beta t^2)}$$

Where  $N_o$ ,  $\alpha$  and  $\beta$  are constants for each liquid,  $t$  = temperature, and  $N_t$  the coefficient of viscosity at temperature  $t$ . For water  $N_o = 0.017793$ ,  $\alpha = 0.03580$ ,  $\beta = 0.0002253$ . For acetic acid  $N_o = 0.016867$ ,  $\alpha = 0.01826$ ,  $\beta = 0.00008537$ .

Slotte gives the relations as follows:

$$N_t = \frac{N_o}{(1 + \beta t)^n}$$

Where  $N_o$ ,  $\beta$  and  $n$  are constants for each liquid.<sup>5</sup>

Still other empirical formulas showing the relation between coefficient of viscosity and temperature are in existence. Some of the constants apply only over limited ranges of temperature. Fig. 6 illustrates the effect of change in temperature upon the flow of water as computed by Poiseuille's rule given above. This shows that change in temperature has a very marked effect on the flow of liquids through porous masses, and is therefore of great importance in filtration.

Of the two types of flow there can be no doubt of the fact that the flow through a filter cake follows that of the non-sinuous or capillary type. This is indicated from the test by the behavior of the flow with respect to pressure.

Considerable investigation has been carried on in the past relative to the flow of water through porous masses

<sup>1</sup>Phil. Trans. Royal Soc. of London.

<sup>2</sup>Phil. Trans. Royal Soc. of London V-LXXIV.

<sup>3</sup>"Comptes Rendus," Vol. 15, 1842; "Mem. serv. Etr.," 1846.

<sup>4</sup>For derivation of this formula see Elements of Physics, Nichols & Franklin, Vol. 1, p. 142; A Text Book of Practical Physics, Watson, 1906, p. 148.

<sup>5</sup>Physico-Chemical Tables, Castell Evans, Vol. 2, p. 629, 1911.



under the subject of underground flow. Darcy\* in 1856 showed that the flow of water through soil varied as follows:

$$v = k \frac{p}{n}$$

Where  $v$  = vel. of ground water,  
 $p$  = pressure at end of soil column,  
 $n$  = length of column.  
 $k$  = a constant for different soils.

Hazen† in 1892 showed that:

$$v = cd^{\frac{h}{e}} (0.70 + 0.03t)$$

Where  $v$  = vel. of flow,  
 $d$  = effective diameter of grain of sand,  
 $t$  = temperature,  
 $h$  = loss of head,  
 $e$  = thickness of sand,  
 $c$  = a constant.

Slichter‡ in 1897 showed that:

$$q = [1.0094] \frac{pd^2s}{\mu hk}$$

Where  $q$  = quantity in c.c.,

$p$  = difference in pressure at ends of cylinder in centimeters at 4 deg. C.  
 $d$  = diameter of soil grains in centimeters,  
 $s$  = area of cross-section of the cylinder in square centimeters,  
 $h$  = height of the column of sand in centimeters,  
 $\mu$  = coefficient of viscosity of the fluid,  
 $k$  = a constant from Table II,

[1.0094] = the logarithm of a factor.

Table II is not here given, as the form of the equation is not affected thereby.

Franklin Kiram King\* in a paper entitled "Principles and Conditions of the Movements of Ground Water," gave the results of a large number of tests showing the rate of flow of water through various porous mediums. In all cases the rate of flow varied approximately as the first power of the pressure.

All of these citations serve to verify the results of the test of the flow through a filter cake, and substantiate the conclusions already reached that the flow through a filter cake varies as the first power of the pressure.

#### EFFECT OF THICKNESS OF CAKE ON RATE OF FLOW

The effect on the rate of flow when the thickness of cake is varied, all other conditions being constant, can be inferred from Poiseuille's formula for capillary flow. This would indicate that the rate of flow varies inversely as the first power of the thickness. Darcy, Hazen, and Slichter have shown that this is true as far as flow through earth, sand and other porous mediums is concerned. It is safe to assume this is so as regards filter cakes also, as the thickness of cake corresponds to the length of tube in Poiseuille's formula.

At this point it is not practical to verify this assumption by actual test in a filter press, because the mathematical tools which will be disclosed later are not yet available. At first thought it would seem as though a test could be made to prove this statement by depositing a cake of a certain thickness and determining its rate of flow and then building up the cake to twice its original thickness and comparing its rate of flow with the first. This is not as simple as it seems, however, as, while it may be practical to deposit two cakes having a

thickness ratio of 1 to 2, it is quite another thing to secure two cakes having a resistance ratio of 1 to 2, because of the equivalent cake thickness of the cloth or filter base, and the effect upon the average thickness due to the grooves in the filter plate or filter support.

Later it will be shown how the above effects can be eliminated by mathematical means, but for the present the proposition that the rate of flow through a filter cake varies directly as the first power of the pressure and inversely as the first power of the thickness must be accepted as true.

#### PERMEABILITY

The above laws apply to flow of liquids through porous masses in general. To make the laws apply to a particular porous mass, another factor must be introduced. The writer can vouch for the fact that the flow through a 1-in. cake of Fuller's earth is quite different in amount from that obtained through a 1-in. cake of kieselguhr under similar conditions. If, however, the rate of flow under known conditions for each of the above substances be ascertained, the rate of flow under any other set of conditions for each one can be deduced from the general laws.

The factor which determines the rate of flow under known conditions may be called the permeability of the substance under those conditions. In order to place the permeabilities of different substances on a comparative basis it is necessary that the permeabilities be given for the same set of conditions. In other words, when the permeability of a certain porous mass is given, it should be understood that the value is that corresponding to a standard set of conditions—the same set to which all other permeabilities are referred.

The most convenient set of conditions to use as a standard in determining the permeability of porous masses are those which have values of unity. The permeability of a given substance may therefore be defined by the rate of flow through a cake 1-in. thick over an area of 1 sq. ft. when the pressure is 1 lb. per square inch. This greatly facilitates the reduction to flow under other conditions, it only being necessary to multiply the standard permeability of the substance by the area and pressure and divide by the thickness to obtain the new flow.

#### UNIT OF PERMEABILITY

A porous mass is said to have a permeability of one when unit pressure produces unit flow through unit thickness over unit area under standard conditions of temperature. In English units a porous mass is said to have a permeability of one when a pressure of 1 lb. per square inch produces a flow of 1 gal. per hour through a thickness of 1 in. over 1 sq. ft. of area at 68 deg. Fahr.

#### UNIT RESISTANCE

The reciprocal of the permeability of a porous mass is its resistance. It is easy to see that the resistance to flow of a porous mass varies inversely as its permeability. This being so, unit resistance may be arbitrarily defined as that resistance which a porous mass of unit permeability has. This unit is as yet unnamed.

#### EQUATION FOR FLOW THROUGH A POROUS MASS

The law governing the flow of liquids through a porous mass may now be expressed as follows:

$$\frac{dQ}{dt} = \frac{P}{Rt} \dots \dots \dots (A)$$

Where  $\frac{dQ}{dt}$  = rate of flow of liquid with respect to time,

$P$  = pressure of mixture,  
 $R$  = resistance of material,  
 $t$  = thickness of material.

\*Les fontaines publiques de la ville de Dijon. Paris.  
 †Some Physical Properties of Sands and Gravels. Rept. Mass. State Board of Health, 1892, p. 541.  
 ‡Theoretical Investigation of the Motion of Ground Water. 19th An. Rep. U. S. G. S., Part 2, 1897-8.  
 19th An. rep. U. S. G. S., Part 2, 1897-8.

### Second Process—Building Up of Cake

There are two things which determine what the thickness of cake produced by a given quantity of a mixture of a solid and a liquid shall be. These are, first, the cake-forming ability of the mixture, and, second, the per cent of solids in the mixture.

#### CAKE-FORMING ABILITY OF A MIXTURE

Mixtures of various substances do not necessarily have the same cake-forming abilities. For instance, 5 gal. of a 2 per cent by weight mixture of kieselguhr and water will, when filtered through 1 sq. ft. of filtering area, produce a cake much thicker than would 5 gal. of a 2 per cent by weight mixture of Fuller's earth and water when filtered through the same area.

#### RATE OF DEPOSITION

The cake-forming ability of a substance when mixed with a liquid may be called the rate of deposition of that substance. A substance is said to have a rate of deposition or a cake-forming ability of one when, under standard temperature conditions, a 1 per cent mixture of the substance with water produces a flow of 1 gal. per hour over an area of 1 sq. ft. when the pressure is 1 lb. per square inch. This unit is also unnamed.

All other things being equal, the thickness of cake produced varies inversely as the rate of deposition. That is to say, having equal quantities of mixtures of the same proportions, but of different kinds of solids, that one requiring the greatest amount of mixture to produce a 1-in. cake will, of course, form the thinnest cake over the same area.

#### PER CENT OF SOLIDS

If a given quantity of a mixture of a solid and a liquid produces a cake of a certain thickness over a square foot of filtering area, one may double the thickness of cake produced by doubling the amount of solids in the given mixture. In other words, the thickness of cake produced by a mixture varies directly as the per cent of solids therein.

#### LAWS GOVERNING THE BUILDING UP OF CAKE

The laws governing the thickness of cake may be stated as follows: The thickness per unit quantity of discharge varies inversely as the rate of deposition and directly as the per cent of solids. Expressed symbolically:

$$t = \frac{\%Q}{k} \dots \dots \dots (B)$$

Where  $t$  = thickness,  $\%$  = per cent of solids,  $k$  = rate of deposition,  $Q$  = total quantity of discharge.

#### Fundamental Law of Filtration

Up to this point the two processes, flow through a porous mass and building up of cake, which constitute the phenomena of filtration, have each been investigated and their laws deduced. It now remains to combine these two sets of laws and thus derive the fundamental law of filtration.

The law of flow through a porous mass is as given in equation (A):

$$\frac{dQ}{dT} = \frac{P}{R_i}$$

In filtration the porous mass is composed of the deposited solids plus the filter base. If the resistance offered to flow by the filter base be designated by  $R_m$ , the rate of flow through the filtering medium would be:

$$\frac{dQ}{dT} = \frac{P}{R_t + R_m} \dots \dots \dots (C)$$

The law governing the building up of cake is given in equation (B):

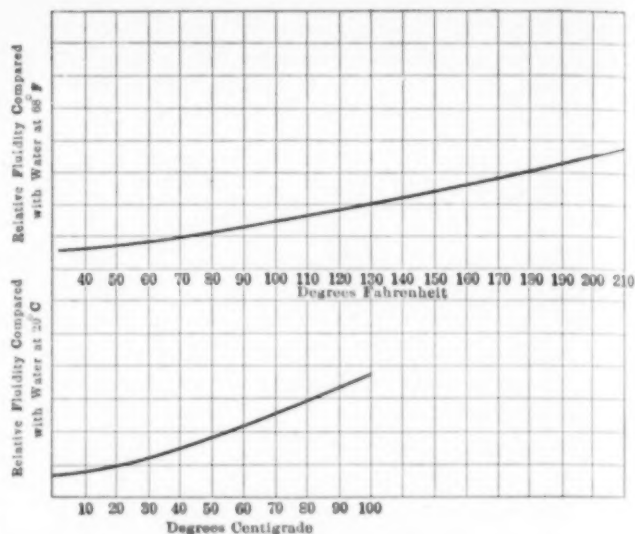


FIG. 6—EFFECT OF TEMPERATURE UPON THE FLOW OF WATER THROUGH A POROUS MASS

$$t = \frac{\%Q}{K}$$

Substituting this value of  $t$  in C:

$$\frac{dQ}{dT} = \frac{P}{\frac{R\%Q}{K} + R_m}$$

$$\text{or } dT = \frac{R\%Q}{PK} dQ + \frac{R_m}{P} dQ \dots \dots \dots (D)$$

In the above  $\frac{dQ}{dT}$  is the rate of flow of filtrate. If the expression is integrated there results the expression of which  $\frac{dQ}{dT}$  is the rate of change of discharge,  $Q$ , with respect to time,  $T$ . Such an expression is nothing more than the equation of the curve showing the relation between  $Q$  and  $T$ . In other words, it is the time-discharge curve from a filter or the fundamental law of filtration.

Integrating  $D$  between corresponding values of  $T$  and  $Q$ :

$$\int_0^T dT = \frac{R\%}{PK} \int_0^Q Q dQ + \frac{R_m}{P} \int_0^Q dQ$$

$$\text{or } T = \frac{R\%Q^2}{2PK} + \frac{R_mQ}{P} \dots \dots \dots (E)$$

In order to determine the value of  $Q$  alone, multiply both sides of  $E$  by  $\frac{2PK}{R\%}$  and add to both sides  $\left(\frac{KR_m}{R\%}\right)^2$ .

This reduces  $E$  to:

$$Q = \sqrt{\frac{2PKT}{R\%} + \left(\frac{KR_m}{R\%}\right)^2} - \frac{KR_m}{R\%} \dots \dots \dots (F)$$

Which is the fundamental law of filtration under standard conditions of temperature.

#### EFFECT OF TEMPERATURE

Temperature of a liquid effects its viscosity and, as shown by Poiseuille's law, the rate of capillary flow is greatly influenced thereby.

To take this effect into consideration in the fundamental equation (F) it is only necessary to multiply the expression for  $Q$  by the amount representing the viscosity for the liquid under standard conditions and divide it by an expression giving the coefficient of viscosity for any other temperature. This must be so, because of the fact that the velocity of capillary flow



and therefore  $Q$  varies inversely as the coefficient of viscosity.

If Poiseuille's formula for relation between coefficient of viscosity and the temperature be used fundamental equation (E) becomes:

$$Q = \left[ \sqrt{\frac{2PKT}{R\%} + \left(\frac{KR_m}{R\%}\right)^2} - \frac{KR_m}{R\%} \right] \frac{N_s}{1 + \alpha t_i + \beta t_i^2} \dots G$$

Where:

$N_s$  = Coefficient of viscosity under standard conditions of temperature, say 68° F and  $\frac{N_o}{1 + \alpha t_i + \beta t_i^2}$

Poiseuille's expression for the coefficient of viscosity at temperature  $t_i$ .

If the values for  $N_o$ ,  $\alpha$  and  $\beta$  at 20 deg. C. for water be inserted in  $G$ , the fundamental equation becomes:

$$Q = \left[ \sqrt{\frac{2PKT}{R\%} + \left(\frac{KR_m}{R\%}\right)^2} - \frac{KR_m}{R\%} \right] (556 + .0199t_i + .0001193t_i^2)$$

Summarizing, it can be seen that filtration depends upon the following seven factors:

- $P$ , the pressure
- $T$ , the time of filtering
- $K$ , the rate of deposition of the mixture
- $R$ , the resistance of the material
- $\%$ , the per cent of solids in the mixture
- $R_m$ , the resistance of the filter base
- $t_i$ , the temperature of the mixture

Two other factors may be added to this list, one, a factor modifying  $P$ , the pressure to allow for the squeezing together of non-rigid solids as the pressure increases, and another to take care of the influence of gravity through the agency of settling or sedimentation.

At first consideration it would appear as though the fundamental equation were too complicated to admit of practical use. Such, however, is actually not the case. It will subsequently be shown how this equation expressing the fundamental laws of filtration can be applied in the solution of practical filtration problems.

Batavia, Ill.

**H. R. Conklin, Joplin, Mo.,** has issued an attractive little booklet describing the Conklin agitator, Conklin directed thickener, and Conklin bag filter.

**Hydrostatic Instruments.**—The Scientific Materials Company, Pittsburgh, Pa., has issued Efficiency Instrument Bulletin No. 4, describing various types of hydrostatic pressure and draft indicators and recorders. These instruments were formerly made in Germany, and are now made by this company.

**Bromine.**—The production of bromine in 1915 was 855,857 lb., valued at \$856,307, an increase of 278,866 lb. in quantity and of \$653,213 in value, according to the U. S. Geological Survey. The high price of bromine during 1915 and the first five months of 1916 was due, in part at least, to an unprecedentedly large demand from abroad. Bromine is made in connection with the manufacture of salt in the Saginaw Valley in Michigan, in the Ohio Valley in Ohio and West Virginia, and in the Kanawha Valley in West Virginia. In Michigan bromine has been marketed in the form of fine chemicals, but as a result of the great increase in demand caused by the war in Europe a large quantity is now being marketed as bromine itself. The bromine produced along the Ohio River, where salt and bromine occur naturally and where there is cheap rail and water transportation and an abundance of cheap coal and gas, has in part been exported to be made into fine chemicals. Here is an opportunity for the American chemist which should not be neglected.

## Some Zinc-Lead Mills of California and Nevada

BY LEROY A. PALMER

It was only a few years ago that a zinc-lead ore presented a problem to the miner that he was unable to solve and that left him worse off than with a straight ore of either metal. Now, thanks to the advance made in the science of concentration, such an ore is no longer a disadvantage and may be so treated that all of the constituents yield a return to the operator.

In the following, brief mention will be made of three mills. Detailed description is not attempted for the reason that none of them involves any new principle, unless we except flotation, but all depend on the fundamentals of concentration.

### The Needles Concentrator

The concentrator at Needles, Cal., Fig. 1, is one of the many plants of the United States Smelting Co. and follows the same general lines that this company first worked out successfully at Midvale, Utah. The ores treated are from the company's mine at Chloride, Ariz., and consist of galena, sphalerite, arsenopyrite and pyrite in a quartz gangue with some lime.

The ore is delivered at the mill in standard gauge, side-dump cars, which run onto a low trestle and are dumped to platforms beneath, Fig. 2. From these platforms the ore is shoveled to half-yard cars and teamed to a small bin below the ground level, from which it is delivered to a 30-in. conveyor 123 ft. long, which runs on an angle of 18 deg. and thus elevates the ore 38 ft. and delivers it to a hopper-bottomed bin. It is fed from this bin by means of a sector gate over an inch grizzly to a 12-in. x 18-in. Blake crusher set to 1 in. and making 240 r.p.m.

The crusher and grizzly deliver to a 14-in. elevator which dumps to two 3-ft. by 8-ft. trommels with  $\frac{3}{8}$ -in. punched screens. The trommel oversize goes to a set of 16-in. by 36-in. rolls, making 70 r.p.m. The roll product is re-elevated to the trommel and the screen undersize goes to a 16-in. conveyor. This conveyor is 56 ft. long on an angle of 18 deg., so that the ore is elevated 17 ft. and delivered to the mill storage bin. From this bin it is fed by a plunger to a wet elevator, which delivers it at the top of the mill to the head of the screen line.

### EXTENDED SYSTEM OF JIGGING AND TABLE CONCENTRATION

The primary screen line consists of three pairs of trommels with wire screens of  $\frac{1}{4}$  in.,  $\frac{1}{8}$  in. and 1/16-in. mesh. The oversize of the trommels goes to eight three-compartment jigs of Harz type with plungers braced by steel straps from the eccentric stems. No



FIG. 1—NEEDLES CONCENTRATOR



FIG. 2—UNLOADING ORE AT NEEDLES MILL

jig product is rejected. The first compartment makes a lead-iron concentrate, the second lead-iron-zinc middling, the third zinc concentrate, while zinc middling discharges over the tailboard.

All middlings from the two coarser jigs go to a slope-bottom dewatering tank, one side of which is at an angle of 45 deg. and a few inches higher than the other. Lying against this sloping side is a 36-in. wheel with curved blades along the circumference, by means of which the middlings are scraped over the upper edge, while the slime overflows the opposite lower edge, passing over a screen for the removal of chips and thence to a Callow tank.

The dewatered middlings go to a set of wet rolls and are then elevated to the secondary screen line consisting of  $\frac{1}{8}$  and 1/16-in. trommels. The oversize of both trommels is reground in a set of rolls which discharges to an elevator and back to the secondary screen line. The undersize of the 1/16-in. trommel goes to a jig similar to the others.

The middlings of the finer jigs, together with the undersize of the last primary trommel, go to settling boxes whose overflow passes to Callow tanks. The underflow is reground in a 4-ft. by 15-ft. tube-mill making 28 r.p.m. The tube discharge goes to an elevator by which it is raised to the Callow tanks.

The underflow of the Callow tanks goes to a three-compartment Harz jig and the overflow is laundered to a modified Calumet classifier, which feeds 15 Wilfley tables. These tables make five products: lead-iron concentrate, zinc concentrate with a small percentage of iron-zinc middling, tailing and slime. The concentrates go to hopper-bottomed boxes with 6-in. discharge plugs by which they are loaded direct to half-yard cars. The middlings are retreated on eight Wilfley tables, which make the same products as the first set. The tailings are retreated on three 6-ft. Johnston vanners, which make zinc concentrates and tailings, and the slimes are treated on three Deister tables, which make the same products as the vanners.

#### FLOTATION OF ZINC-BEARING SLIME

The Deister tailings and some of the original slime, amounting altogether to 20 tons per eight-hour shift, are retreated in a flotation plant for the further recovery of the zinc. This consists of three Callow cells. The pulp is agitated under 7 to 8-lb. air pressure in a small Pachuca tank in which it is mixed with oil and acid. The consumption of these materials in treating 20 tons per shift is 250 lb. of sulphuric acid and 10 to 16 lb. of oil, consisting of 75 per cent creosote and 25 per cent pine oil. The feed is distributed between two cells, the tailings of which are pumped to a third cell. No finishing cells are used, but the concentrates are

run direct to two Oliver filters for dewatering. The product of the flotation plant is zinc concentrate.

The mill has a capacity of from 200 to 225 tons per day. The concentration ratio on all products is 1.8 to 1, with one ton of lead concentrate to 4.2 tons of crude and one ton of zinc concentrate to 3.5 tons of crude. The zinc extraction is from 70 to 73 per cent and the total extraction is in excess of 90 per cent.

#### Yellow Pine Mill

The 100-ton mill of the Yellow Pine Mining Co. at Good Springs, Nev., is, strictly speaking, a separator rather than a concentrator. The ore is a high-grade lead-zinc material, and in the treatment at this plant no rejection is made, all products of the mill being shipped.

The ore is hauled from the mine in narrow-gage cars and dumped to the mill bins. It consists principally of lead carbonate and zinc carbonate and silicate. Sulphides are almost entirely absent as evidenced by the fact that the smelter returns on the lead concentrates show only 2 or 3 per cent sulphur.

From the mill bin the ore is fed to a short conveyor, on which the larger pieces of waste are sorted out. This conveyor dumps over a 1-in. grizzly and the oversize goes to an 8-in. by 16-in. roll-jaw crusher. Grizzly and rock breaker both discharge to a chain elevator, which dumps to the fine-ore bin.

The fine ore is delivered by a shaking feeder to a set of 16-in. by 36-in. Cornish rolls set to  $\frac{1}{4}$  in. These discharge to a wet elevator, which raises the ore to the top of the mill, where it passes successively over  $\frac{1}{4}$ -in. and  $\frac{1}{8}$ -in. Impact screens. The screen oversize is treated on two 2-compartment Harz jigs, which make lead concentrates from the bed and hutch of the first compartment and middlings through the second compartment and over the tailboard. The middlings from the coarse jig are returned to the first set of rolls and those from the finer jig to a second set, both of which discharge to the elevator and to the Impact screens.

The undersize of the second screen goes to a five-compartment Richard's classifier, which makes six products, each of which goes to an Overstrom table. The tables make only two products, lead and zinc concentrates. The lead goes to tubs and the zinc, with all slime to settling bins beneath the table floor. The lead is shoveled to small cars, the zinc is drawn off through gates and the slime overflows to ponds from which it is shoveled out and shipped when a sufficient amount accumulates.

Under this system an extended run of 16,136.3 tons of crude ore assaying 10.2 per cent lead, 31.8 per cent zinc and 5.4 oz. silver produced 1521.085 tons of lead concentrate averaging 53.2 per cent lead, 13.75 per cent zinc and 28.1 oz. silver; 11,260.65 tons of zinc concentrate assaying 33.2 per cent zinc, 4.4 per cent lead and 2.5 oz. silver, and 2173.0 tons of slime averaging 7.3 per cent lead, 35.1 per cent zinc and 4.0 oz. silver; 833.4 tons of waste was removed by sorting. During 1915 milling cost was \$1.53 per ton.

#### Anchor Mill

The Anchor mill is characteristic of several dry mills that have been installed in the Good Springs district recently and uses a Stebbins table for concentration.

The ore is fed from the bin over a 1-in. grizzly to an 8-in. by 12-in. Dodge crusher set to  $\frac{3}{4}$  in. The grizzly and crusher product go to a set of 14-in. by 30-in. rolls set to  $\frac{1}{8}$  in. The roll product is elevated to an 8-ft. trommel with 8-mesh ton-cap screen, the oversize of which returns to the rolls and the undersize goes without further classification to a No. 6 Stebbins table with a capacity of two tons per hour.



## PNEUMATIC CONCENTRATING TABLES USED

There are three products from this table: dust, which is removed by a fan and stacked behind the mill, lead concentrate, and either zinc concentrate or tailing, according to whether a zinc-lead or a lead ore is being treated. The lead concentrate is run to a bin by a conveyor belt and a screw removes the tailing or zinc product to another bin to be loaded to cars and wasted or shipped as the case may be.

The Stebbins table is made in seven different sizes, the extreme capacity of the largest size being 12 tons



FIG. 3—ANCHOR MILL, GOODSRING, NEV.

per hour. In general design and principle of action it is similar to the standard makes of riffle-deck water tables. The shape of the deck is similar to that of the Wilfley and it is provided with longitudinal riffles, all of which extend clear to the concentrate end.

The deck is of sheet metal with perforated slots which have a slanting lip over each so as to direct the air current through the ore layer at an angle instead of directly upwards. Beneath the deck is an air chamber into which a blower forces air, at a pressure varied to suit conditions, and from which it escapes through the slots in the deck. The table has a reciprocating motion and stratifies the ore as on a water table, simply using air as a medium instead of water.

All machinery—crusher, trommel, rolls, elevator and table—is tightly housed and the dust is drawn off by a 30-in. fan. While this ameliorates conditions, the mill is, at best, very dusty and employees wear respirators.

By this system a lead-zinc ore carrying 35 per cent lead and 24 per cent zinc is separated into a lead concentrate assaying 67 per cent and a zinc concentrate carrying 34 per cent zinc and 6 per cent lead.

On a straight lead ore the saving approximates 65 per cent. This saving appears low, but it should be borne in mind that at this mill the dust, which has about the same metal content as the original ore, is not treated and the process is comparable with a wet mill that does not treat its slimes.

San Francisco, Cal.

The Kansas Chemical Co., Hutchinson, Kan., has taken up water purification as a side line of its regular work. The development has been in charge of Leslie C. Hughes.

The American Alkali & Acid Co., Bradford, Pa., is planning an extension of its plant. The equipment is at present being obtained for the manufacture of toluol, benzol, anthracene, naphthalene, creosote, phenol, hard pitch and ammonia.

## Practical Methods for Testing Refractory Fire Brick\*

BY C. E. NESBITT AND M. L. BELL

The use of refractory material in metallurgical operations is one which, as a rule, is given but very general consideration. The selection of a suitable refractory calls for a study, first, of the temperatures involved, and secondly, of the nature of the hot material and resulting slag to which the refractory will be exposed.

Refractories are generally used in form of bricks or blocks which are molded from materials in the plastic condition, then burned. The resulting product is a solid of sufficient mechanical strength to permit its use for various forms of construction.

The two most common raw materials for making refractory bricks are clay and a variety of silica called ganister. Other raw materials are gradually finding wider and more general use, but these two continue to be the important ones.

Clay and silica rock suitable for bricks are widely distributed, but nature has very largely determined their physical properties. Each of these materials has varying physical properties which may be taken advantage of and incorporated into the finished bricks, the quality of which is largely dependent on the methods employed in their manufacture.

In its simplest terms a furnace or heating chamber consists essentially of a shell of brick work sometimes bound together with a suitable framework of iron. Owing to various physical, chemical and mechanical operations which take place in the furnace, the refractory must meet certain demands to give a satisfactory life. No brick can be expected to be best in all physical properties, and it becomes necessary to select the brick which is best suited to withstand that particular condition imposed by the furnace. It may be that the brick will have to withstand the abrasive action of heavy, hard materials, the sudden fluctuation of temperature, the corrosive action of slag, or the action of load while at high temperatures. These and similar points should be considered, their relative importance determined, and the brick chosen should be the one best suited to resist that particular condition.

In the iron and steel industry the blast furnace is one of the most important types of furnaces. In simple terms it is a hollow steel cylinder, approximately 100 ft. high and some 28 to 30 ft. in diameter, lined with fire brick. In a furnace of 500-tons capacity about 1900 tons of ore, limestone and coke are used every 24 hours. These materials, often wet or frozen, are fed in at the top and fall on the materials already in the furnace or roll over against the walls. Since this material must pass slowly through the furnace, the wear of the lining is extremely heavy. The temperature at the top of a blast furnace is low, but as the charge descends the temperature increases until the fusion zone is reached. In this zone the hard material composing the charge becomes a pasty mass which ultimately is melted, and the brick work then has to withstand molten iron and slag rather than abrasion or impact.

No blast furnace is complete without its battery of stoves in which no metallurgical operations take place. The object of the stove is to absorb heat rapidly and then as quickly give it up. Here a brick must withstand sudden thermal changes, abrasion, slagging, due to the dust carried by the burning gas, and possess good heat-absorbing qualities.

In one of the processes of converting pig iron into steel a basic open-hearth furnace is used. This furnace

\*A paper presented at the Atlantic City meeting, June, 1916, of the American Society for Testing Materials.

is built up largely of silica brick, although the hearth is made up of basic materials because of the basic character of the slag, while the regenerators are of fire brick. Silica bricks are very sensitive to thermal changes, but owing to their infusibility and their ability to withstand heavy loads when highly heated, they are used almost without exception in open-hearth practice. Any variation in manufacture of material which will tend to decrease their sensitiveness to heat changes, without sacrifice to their other good qualities, will directly increase the life of the furnace.

In soaking pits, heating furnaces, annealing furnaces, mixers, ladles, etc., the temperatures are not as high as in the open-hearth furnace; the brick work here has mainly to withstand the action of the molten metal, iron scale, or slag.

A general review of the conditions imposed on fire brick as used about iron and steel plants has pointed out two general conclusions: (1) the life of a furnace is determined by the life of its brick work, and (2) different furnaces demand different physical properties in the brick used.

#### DESCRIPTION OF TESTS

A great many investigators have attacked the problem of refractories, the work having been done mainly from the standpoint of the inherent physical properties of the raw materials. The results are of high technical excellence and have been of value. In the majority of cases, however, the tests have not been applicable to brick as received by the consumer. He could not go out to his stock, select several bricks and quickly determine their value for his particular purpose.

With this idea in mind each of the various conditions where fire brick are used was studied to determine the cause of failure. The next step was to imitate actual conditions of service in the laboratory. This meant that tests must be employed which were very severe, producing in a short time what in actual service might require months, or even years to accomplish. To test brick cold and say that the result of the cold test was a measure of the performance when hot did not seem justifiable. Another point was to make the tests such that the work could be done on the brick as received, and not on bricks prepared for the test.

In the study of service conditions, attention was first

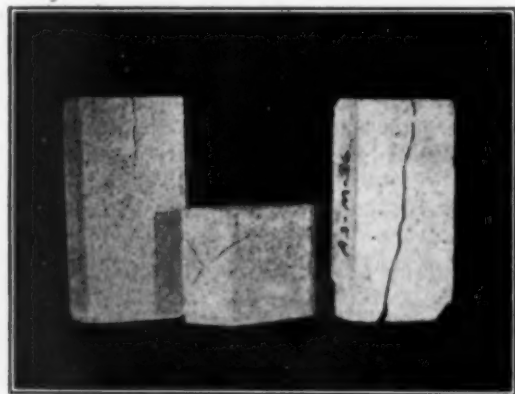


FIG. 1—IMPACT TESTS, ILLUSTRATING CHARACTERISTIC FRACTURES

directed to the top of the blast furnace. The average temperature at the top is about 260° C. The charging of a furnace is a nearly continuous operation, the material charged falling on the large bell, which, when lowered allows the material, often wet or frozen, to slide off the bell and strike the walls of the furnace. Immediately the charge starts slipping and grinding its way slowly downward past the brick in the wall. These

conditions required tests that would imitate impact, abrasion and spalling.

**Impact Test.**—An impact test was first considered. The rattler and other similar tests were studied, but it was finally decided that some kind of a drop test would be the most practical, and would most nearly approach service conditions. After trying many shapes and sizes of falling weights it was finally decided to use a steel

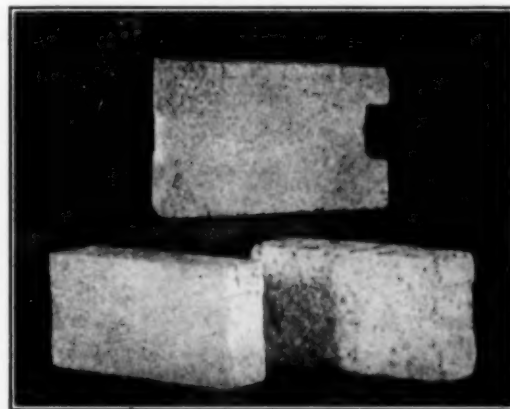


FIG. 2—ABRASION TESTS, SHOWING DIFFERENCE IN DEPTHS OF CUTS IN UPPER BRICK

ball  $2\frac{1}{2}$  in. in diameter. The brick was heated to 260° C. and the ball allowed to drop on the end of the brick from a height of 2 in., then 4 in. and so on, until the brick broke. The height to which it was necessary to raise the ball to cause fracture of the brick represents a particular quality, namely, resistance to impact.

The comparative strengths of brick to resist impact at ordinary temperatures and at slightly elevated temperatures is interesting. A brick heated to 260° C. and tested was 20 per cent weaker than a brick of the same brand tested at 20° C., and 40 per cent weaker when tested at 540° C. (Fig. 1).

**Abrasion Test.**—In developing an abrasion test it was



FIG. 3—SLAG PENETRATION AND ABRASION ON SILICA BRICK—PORTION OF AN 18-IN BULKHEAD

found that others had abraded brick in the cold by means of an emery wheel. This idea was modified so as to test the brick while hot. A temperature of 260° C. was adopted for top-wall and pipe brick, and 1350° C. for all others. The reason for choosing 1350° C. for the high temperature was that (1) it is a comparatively easy temperature to reach with a test furnace, and (2) while it might not represent the highest temperature in the



furnace, it is above the melting point of cast iron, and is applicable to all high-temperature furnaces used about iron and steel plants.

The brick to be tested was heated to 1350° C. and then pressed against a carborundum wheel, pressure and time being constant. When the brick became cold the depth of cut was measured and the result reported as linear inches abraded in 5 minutes. This test developed the interesting fact that bricks are not always the same at both ends, for it was found that sometimes there may be 10 to 20 times as much abrasion at one end as the other (Figs. 2, 3, 4 and 5).

*Spalling Test.*—Spalling was next studied. In brick work such a condition is usually the result of thermal changes, often accelerated by mechanical pinching. In actual service only one surface, generally the end or side of the brick, is exposed to the direct action of heat.

After trying various tests it was decided to place the brick to be tested in the wall of the furnace so that only one end was exposed. The testing temperature was

confined by the use of kaolin rings, but both tests were unsatisfactory. To confine a comparatively large portion of slag to any one portion of the brick it became necessary to drill a cavity in the brick and place the slag therein. Experiments were made to determine the effect of fineness of the slag, time of exposure to heat, and the effect of destroying the surface texture by drilling. To measure the slag penetration the brick is cut through the pockets of the slag and the area of brick penetrated by the slag measured with a planimeter (Figs. 8, 9 and 10).

**Compression Test.**—The ability of brick work to stand up under loads when highly heated is of great importance. A comparative test consisting of a modified Brinell ball test was used by heating the brick to 1350° C., removing from the furnace and then forcing a 2½-in. steel ball into the brick under a pressure of 1600 lb. The depth of the impression was then measured when cold (Figs. 11 and 12).

*Expansion, Contraction and Fusibility.*—These are important qualities of fire brick. For these tests the

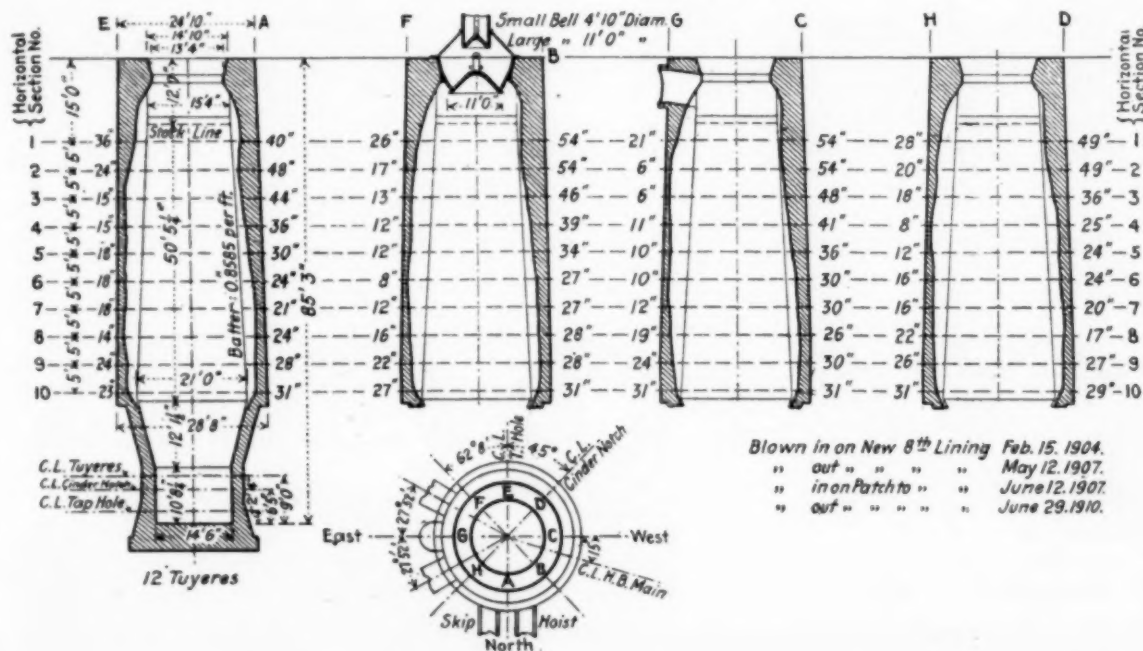


FIG. 4—VERTICAL LINES OF EROSION ON A BLAST FURNACE AFTER SIX YEARS' SERVICE—UNIFORM WEARING

NOTE.—The letters *E, A*, etc., represent vertical sections taken on the diameters shown in the plan; the figures 1, 2, 3, etc., shown at the left and right, designate the horizontal sections, which are shown in Fig. 5. The figures on the outside of the vertical sections represent the thickness of the brick lining remaining at these points.

1350° C., and after a series of experiments as to the most satisfactory time for heating, one hour was decided upon, with 25 minutes' cooling in a blast of air. To produce a measurable spall at least 30 operations of heating and cooling were required. This was too long, and it was decided to increase the severity of the test by cooling in water for 3 minutes, and so hasten the spalling. A series of tests determined that cooling in water was three times as effective as air cooling. The number of operations was accordingly cut down to ten. The amount of spalling is reported as the percentage loss in weight. This test applies only to fire brick (Figs. 6 and 7).

**Slagging Test.**—The failure of brick work due to the corrosive action of slags is more prevalent than any other cause. Not only is the slag action marked in blast furnaces but also in open hearths, cupolas, and heating furnaces, and to a lesser degree in mixers, ladles, fireboxes, etc.

During the development of a slag test the slag was first placed on the surface of the brick. It was next

usual methods were followed, and they need not be mentioned further at present (Figs. 13 and 14).

## RESULTS OF TESTS

As a result of a large number of tests following the methods which have been outlined, it was found that fire bricks tended to group themselves according to density. In general, bricks of high density, all other factors being equal, have the most desirable qualities, namely, least abrasion, good resistance to slag and least compression. Spalling is very slightly increased, but not to a dangerous extent if bricks are not over-burned.

As a measure of density, the apparent specific gravity is used—obtained by weighing and measuring the brick and not by suspension, as is usually done. Results show that various makes of brick have characteristic values for apparent specific gravity and that the method of manufacture greatly influences the density. A series of preliminary experiments had shown the importance of pressure and moisture in producing a dense brick, and this test was followed up by a more elaborate series. A

TABLE I—RESULTS OF TESTS ON FIRE BRICK OF VARYING MOISTURE CONTENT

Properties Considered	PERCENTAGE OF MOISTURE					
	4	6	7	8.5	10	12
Apparent specific gravity	2.11	2.17	2.19	2.16	2.10	2.06
Compression at 1350 deg. C., depth of impression, in.	0.49	0.44	0.43	0.51	0.53	0.57
Expansion per foot of length at 1350 deg. C., in.	0.064	0.064	0.045	0.045	0.049	0.050
Impact at 260 deg. C., height of drop, in.	18	33	45	35	31	30
Abrasion at 1350 deg. C. in five minutes, in.	0.024	0.008	0.012	0.016	0.028	0.020
Blast-furnace slag, sq. in.	0.37	0.30	0.24	0.28	0.43	0.36
Open-hearth slag, sq. in.	0.82	0.48	0.58	0.66	0.66	0.74
Heating-furnace slag, sq. in.	1.05	0.35	0.29	0.42	0.42	1.26

standard fire-clay mixture was used, in which the moisture was varied from 4 to 12 per cent, and all bricks were pressed at 2000 lb. per sq. in., then burned in a regular kiln. Results of tests applied on this series are shown in Table I and Fig. 15.

TABLE II—RESULTS OF TESTS ON A HIGH-PRESSURE, LOW-MOISTURE BRICK AND A HAND-MADE, REPPRESSED, ORDINARY-MOISTURE BRICK

Properties Considered	KIND OF BRICK	
	Pressure of 1500 Lb. per Sq. In., Moisture, 7 per Cent	Hand Made, Repressed, Ordinary Moisture
Compression at 1350 deg. C., depth of impression, in.	0.29	0.55
Expansion per foot of length at 1350 deg. C., in.	0.062	0.059
Impact at 260 deg. C., height of drop, in.	45	28
Abrasion at 1350 deg. C. in five minutes, in.	0.02	0.04
Spalling, loss, per cent	9.4	10.6
Slag penetration, Blast-furnace slag, sq. in.	0.27	0.56
Heating-furnace slag, sq. in.	0.26	0.67

Conclusions can only be drawn when all conditions except brick quality are the same.

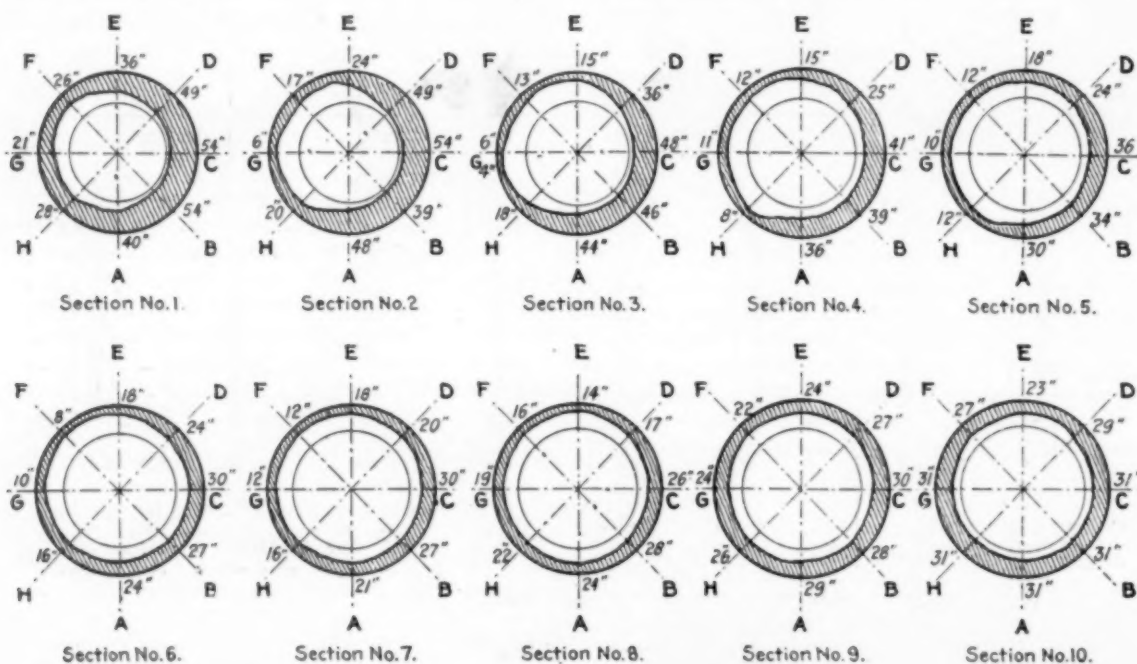


FIG. 5—HORIZONTAL LINES OF EROSION ON A BLAST FURNACE AFTER SIX YEARS' SERVICE—UNIFORM WEARING

NOTE.—The letters at the ends of a diameter refer to the corresponding section indicated in the plan view of Fig. 4. The figures at the ends of a diameter indicate the thickness of the brick remaining at the ends of that diameter. For example: Horizontal section No. 1 shows thicknesses at the ends of the diameter EA equal to 36 and 40 in.; at the ends of diameter FB, 26 and 54 in., etc. These figures will also be found along the horizontal line of section No. 1, in Fig. 4.

Power-pressing a brick during manufacture up to 1500 lb. per sq. in. has been found to materially improve the quality of most fire brick; beyond that figure very little improvement is made. A comparison of tests on a high-pressure, low-moisture brick and a hand-made, repressed, ordinary-moisture brick, both brick of the same mixture, is given in Table II.

The laboratory methods suggested have been developed mainly with reference to bricks to be used in iron and steel plants. When modified they are applicable to almost any condition of service to which the bricks will be subjected. If a brick is to be used in a boiler setting, copper<sup>o</sup> or lead smelter, calcining or roasting furnaces, the test should imitate these conditions, in order that the results be comparative. Conditions of service must be studied to learn what is demanded of a brick.

When a laboratory test has been developed it must be confirmed by actual service tests. To compare the life of two similar furnaces built of different materials, or even the same furnace built of different materials at different times, does not necessarily mean that the material showing the longest life is the better, since the operating conditions may have been decidedly different.

To derive the greatest benefit the consumer and manufacturer must work together. The manufacturer's interest must not cease with the shipment of his product. The consumer should provide all reasonable facilities for the manufacturer to study his product in actual service. It is only by such co-operation or exchange of information that the best results can be obtained. A more detailed description of apparatus and methods is appended.

## APPENDIX

### Methods of Testing Refractory Fire Brick<sup>1</sup>

#### IMPACT TEST

**Construction of Apparatus.**—The machine for determining the resistance to impact consists of two vertical uprights 15 ft. high, supporting two vertical and parallel 1½-in. angle irons. The angle irons are placed so that their inclosed angles face each other and are braced 3¾ in. apart measured from the inside of the

<sup>1</sup>At the present time the machines and apparatus here described are in a state of development, and while they have been standardized for the test, the machines and methods themselves are not necessarily final.



angles so as to allow a ball  $2\frac{1}{2}$  in. in diameter to fall freely between them, the sidewise movement of the ball not to exceed  $\frac{1}{4}$  in. These angle irons are adjusted so that bricks of different heights may be placed under them, and are marked, beginning at the lower ends, so as to clearly designate successive heights of 2 in. The test specimen is placed directly below the angle irons on a steel block of sufficient size to give a solid foundation. The upper face of the block is perfectly smooth and at

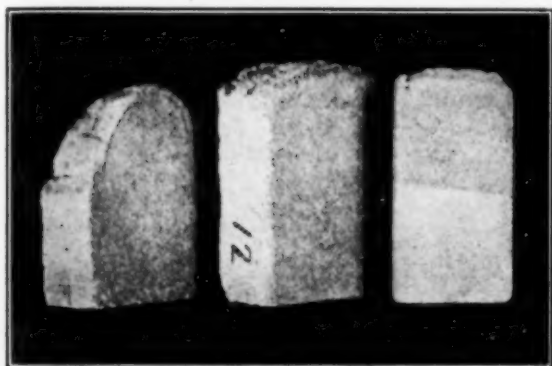


FIG. 6—CHARACTERISTIC SPALLING-TEST SPECIMENS

right angles to the angle irons. The block is  $6\frac{1}{2}$  by 15 by 12 in., and weighs 332 lb. The falling weight is a steel ball  $2\frac{1}{2}$  in. in diameter weighing 2.34 lb.

**Operation of Test.**—The brick to be tested is first carefully inspected, and, if necessary, ground on a carborundum wheel so that it sets firmly on one of its ends. On the other end of the brick the diagonals are then drawn to locate the center. The brick is now placed in a cold furnace and heated at a uniform rate from atmospheric temperature to  $260^{\circ}\text{C}$ ., so that at least one hour is required to reach the final temperature. The final temperature ( $260^{\circ}\text{C}$ .) is maintained for not less than three hours.

The brick is now ready for the test and is placed on

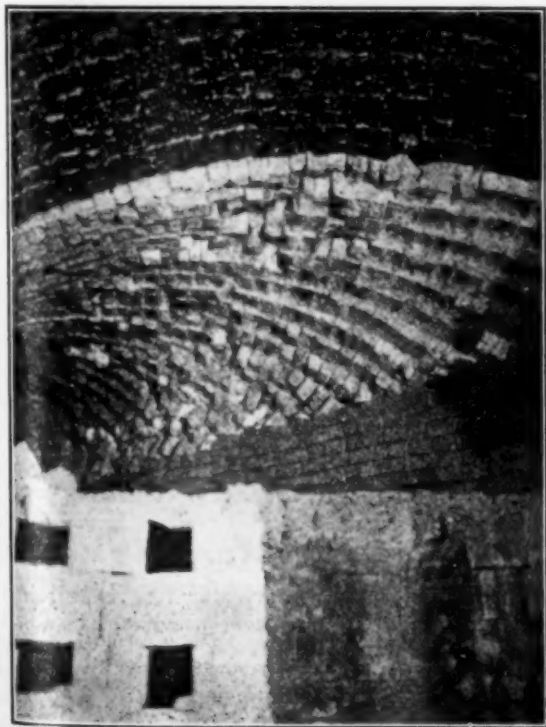


FIG. 7—SPALLING IN ROOF OF AIR FLUE OF OPEN-HEARTH FURNACE

(Note similarity between actual and test spalling)

the steel block, so that the ball between the angle irons touches the brick at its marked center. Iron blocks are placed around the brick until they are nearly level with the top of it, to prevent sidewise movement, but the brick is not wedged. The ball is now dropped from a pair of tongs on the end of the brick at successively increasing heights of 2 in. until the brick fractures. Any fracture radiating 1 in. or more from the point of contact of the ball is considered a fracture, and the distance in inches of the last drop is the result of the test. If the ball is allowed to drop again from the last height the brick

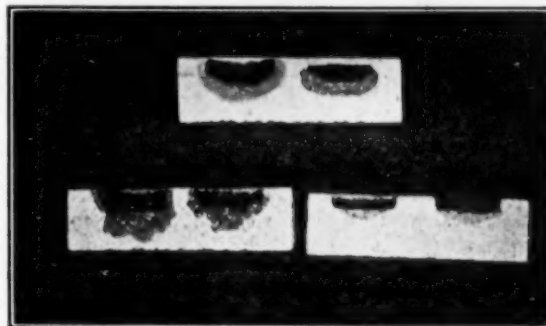


FIG. 8—CHARACTERISTIC SLAG-TEST SPECIMENS

gives off a dead or broken sound. The clear ring of a sound brick has disappeared.

#### COMPRESSION TEST

**Construction of Apparatus.**—The machine for determining the resistance to compression is a modified Brinell ball testing machine and consists of a 4-in. I-beam 10 ft. long and weighing 75 lb., so arranged as to act as a second-class lever arm; that is, one end is the fulcrum and at the other end the weight is applied so as to produce the compression on the brick placed 6 in. from the fulcrum. All bearings are knife-edged. The fulcrum end of the bar is mounted between two vertical uprights, 10-in. channel irons and so arranged that the height of the fulcrum may be adjusted by a hand wheel to suit bricks of varying thickness. Six inches from the fulcrum towards the weighted end of the bar a spherical

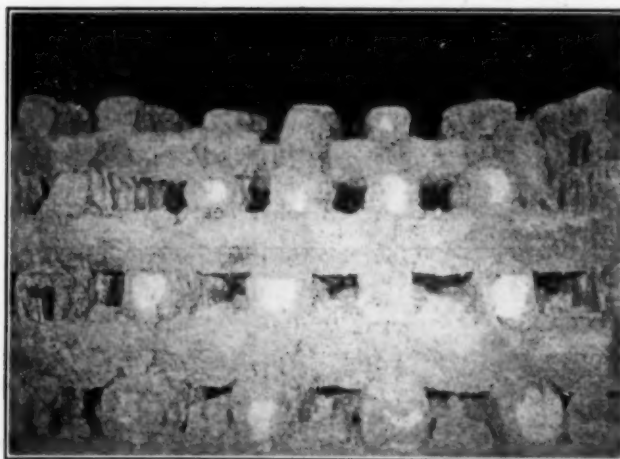


FIG. 9—CHECKERS IN GAS CHAMBER OF OPEN-HEARTH FURNACE, SHOWING SLAGGING

depression marks the location of the ball. The ball is a steel ball  $2\frac{1}{2}$  in. in diameter weighing 2.34 lb. The brick to be tested rests on a solid foundation directly below the depression. The bar alone produces a pressure of 850 lb. on the ball, and the balance of the weight is added at a uniform rate of 25 lb. per second by means of dry sand, which flows from a hopper into a bucket at-

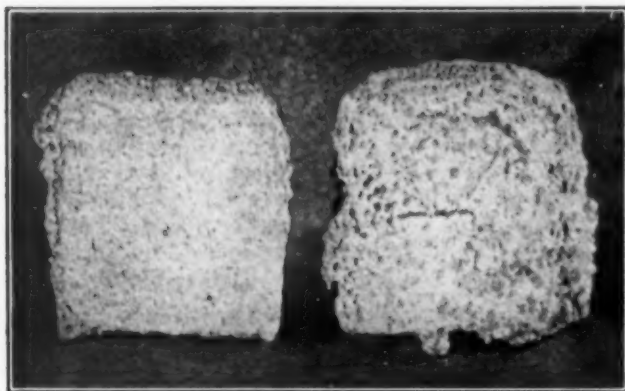


FIG. 10—INDIVIDUAL CHECKERS FROM GAS CHAMBER OF OPEN-HEARTH FURNACE, SHOWING SLAG PENETRATION

tached to the end of the bar. Bar and sand together produce a total load on the ball of 1600 lb.

*Operation of Test.*—The brick to be tested is placed in a cold furnace and heated slowly to 1350° C. The heating as a convenience is done over night at a uniform rate not to exceed 260° C. per hour. Total time of heating should in no case be less than 6 hours. The brick before testing should be maintained at 1350° C. for not less than 3 hours.

The brick is now removed from the furnace and placed flat on the foundation beneath the bar, and the bar lowered so that when the ball is in position in the depression it is also in contact with the center of the upper surface of the brick. The weighted end of the bar is then gently released and the flow of sand immediately started. The time required to remove the brick from the furnace and apply the load is less than one minute. The pressure is maintained for five minutes, starting from the time the bar is released. The brick is then removed from the machine and allowed to cool. When cold the depth of penetration produced by the ball is measured by placing centrally over the depression a flat rectangular plate 3½ in. sq. (¼ in. thick), at the center of which is mounted at right angles to it a Brown & Sharpe micrometer depth gage. The lower end of the stem of the micrometer is rounded so that it has the same radius as the 2½-in. ball. The depth at the center of the depression is measured to 0.001 in.

#### ABRASION TEST

*Construction of Apparatus.*—The abrasion testing machine consists of a carborundum wheel mounted on a suitable stand and revolving vertically. In front of the wheel and resting on the stand is an L-shaped plate 6½ by 16 by ¼ in. resting on roller bearings and forced

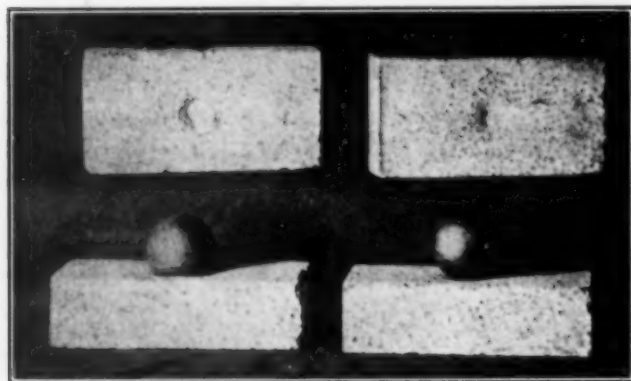


FIG. 11—CHARACTERISTIC COMPRESSION-TEST SPECIMENS, SHOWING DEPTH OF BALL AND CORRESPONDING IMPRESSIONS

towards the wheel by means of a right-angle lever arm, and suspended weights. The upper surface of this plate is 1¼ in. below the horizontal radial line drawn from the center of wheel. All points of contact on the lever arm are knife-edged and friction is reduced to a minimum. The carborundum wheel is 18 in. in diameter, has a 2-in. face and 1½-in. center hole, and is purchased from the Carborundum Company, grit 16; grade J; bond G-5. The wheel is motor driven and has a surface speed of 1640 ft. per minute and is to be redressed when the corners wear away ¼ in. of their original radius, or as soon as the face ceases to be at right angles to the side of the wheel. The pressure of the brick against the

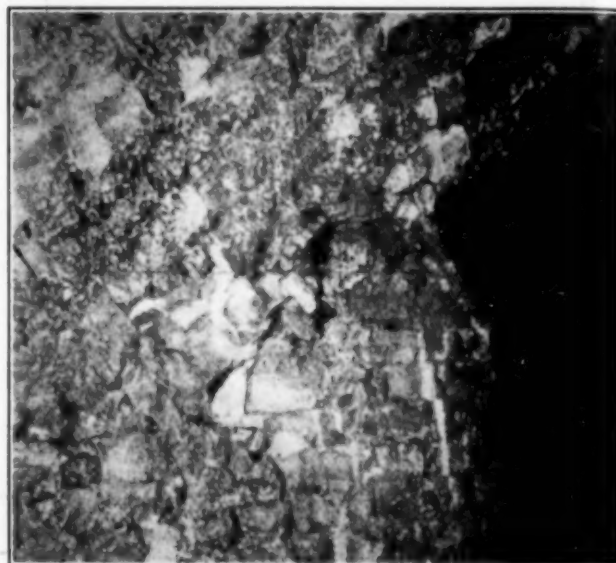


FIG. 12—SPALLING, ACCELERATED BY COMPRESSION, OF ENTIRE CORNER OF AIR FLUE IN OPEN-HEARTH FURNACE

wheel is 10 lb. per sq. in. of brick in contact with the wheel, excluding the pressure required to move the brick.

*Operation of Test.*—The brick before testing is ground cold to a uniform thickness of 2.35 in. for 2½ in. brick, and for 2.80 in. for a 3-in. brick, and the ends ground so that the testing wheel cuts through this thickness. The depth of this preliminary cut is measured at its center, using the rectangular plate described under the compression test. The brick prepared for test is heated

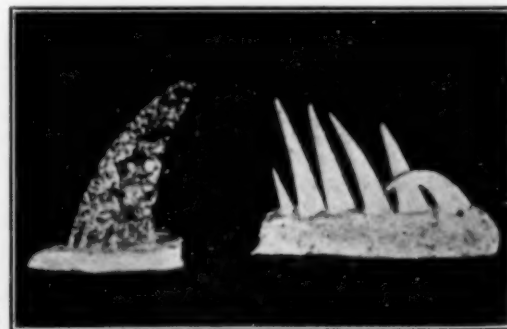


FIG. 13—CHARACTERISTIC SOFTENING-TEST SPECIMENS

the same as under the compression test, except in the case of top-wall and pipe brick, which are heated the same as for the impact test.

The brick is then removed from the furnace, placed flat on the plate in front of the wheel so that the wheel enters the preliminary cut, and is then abraded for five minutes. The time is taken with a stop-watch. In the case of soft brick, which abrade very rapidly, the test is run for a fraction of the period, and then calculated



to the five-minute period. The brick is now returned to the furnace and reheated for not less than one hour. The test is then repeated on the other end of the brick. When cold the depth of cut on both ends is measured, and the difference between the preliminary and the final cuts is the result reported.

#### SPALLING TEST

*Operation of Test.*—Preparatory to the test the fur-

minutes. The bricks are then removed and allowed to dry for three minutes in air. To indicate three-minute periods a stop-watch is used. The bricks are then placed in the doorway of the furnace as before, and the operation repeated for a total number of ten times. The bricks are now dried at 100° C. for at least five hours, and all particles which can be easily broken off with the fingers removed. The bricks are then weighed and the percentage of loss calculated from the original weight.

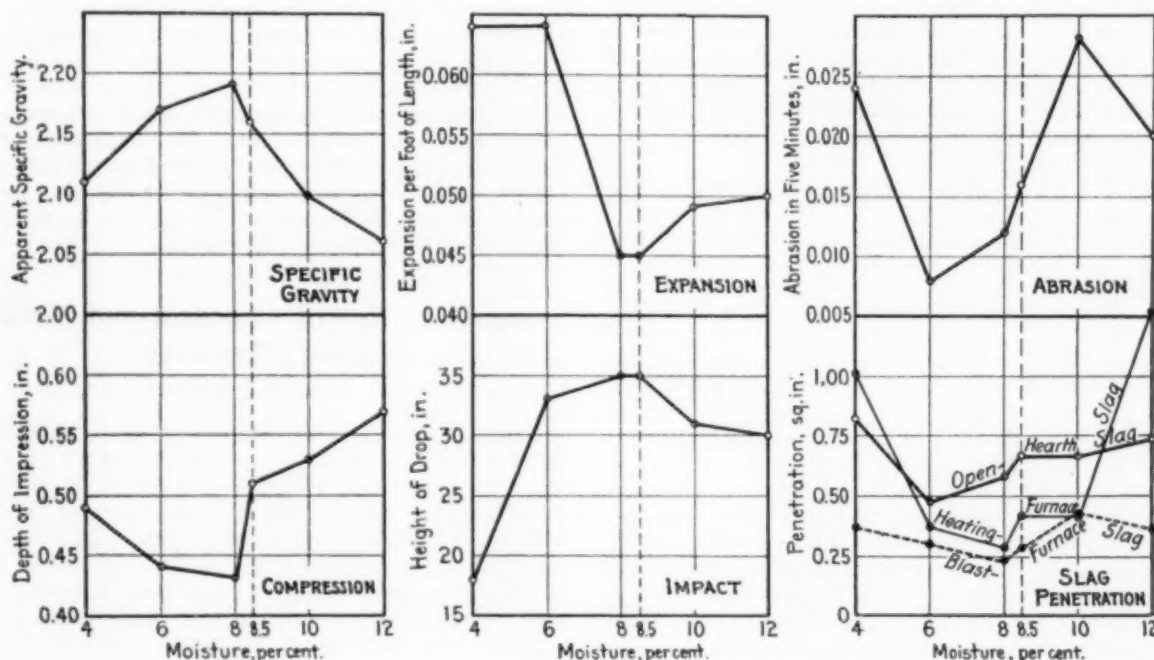


FIG. 15—INFLUENCE OF WATER USED IN MANUFACTURE ON PHYSICAL PROPERTIES OF FIRE BRICK

nace is heated to 1350° C. and held at this temperature for about one hour. The bricks to be tested are dried at 100° C. for at least five hours, weighed, and then placed in the doorway of the furnace, their ends flush with the inside of the wall. In case a sufficient number of bricks are not being tested to entirely fill the doorway, the remainder of the space is filled in with other bricks to insure heating the ends only. The bricks are now heated for one hour and plunged separately into 2 gal. of water at 20° C. to a depth of 4 in. and held there for three

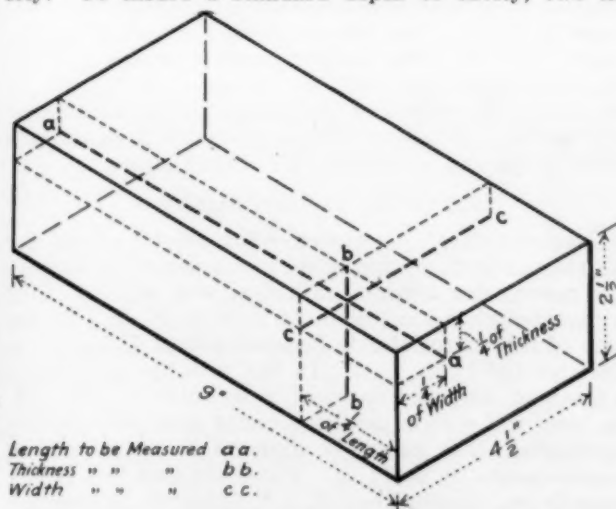


FIG. 14—GAS AND AIR PORTS INSIDE OPEN-HEARTH FURNACE

(Note slagged condition of walls and roof, and total disappearance of brick around water cooler in foreground.)

#### SLAGGING TEST

*Operation of Test.*—In preparing the sample for the slagging test, the 9 by 4½-in. unbranded side of the brick is bisected by a line across the narrow dimension and diagonals drawn on each half. At each intersection of the diagonals a circular cavity is drilled 2½ in. in diameter and ½ in. deep at the sides. The drills are 5/16 in. thick and 2½ in. wide, measured diagonally across opposite corners, while the point of the drill includes an angle of 150 deg. A template is made of 3/16-in. sheet steel to insure that all drills are ground properly. To insure a standard depth of cavity, two in-



Length to be Measured a a.  
Thickness " " b b.  
Width " " c c.

FIG. 16—AXIS ALONG WHICH MEASUREMENTS ARE TAKEN IN DETERMINING THE SIZE OF A BRICK

verted U-shaped pieces of metal are clamped to each drill when in use and adjusted so that drill cannot enter the hole more than  $\frac{1}{2}$  in., measured on the side of the drill. The cross-section of the cavity passing through the deepest point has an area of 1.7 sq. in., and is checked up for size and depth by a template. The pressure used in drilling must not be so severe as to partially crack the brick.

After the cavities have been drilled and cleaned of loose material the bricks are placed level in a cold furnace and heated as in the compression test. When 1350° C. is reached 35 g. of standard blast-furnace slag are placed, by means of a long rod with a spoon-shaped end, in one cavity, and 35 g. of standard heating-furnace slag in the other cavity. The slags used shall have approximately the following analysis and melting points:

	Blast-Furnace Slag	Heating-Furnace Slag
Silica ( $\text{SiO}_2$ ), per cent.....	38.0	35.0
Iron (Fe), per cent.....	1.5	44.0
Manganese (Mn), per cent.....	1.0	0.5
Alumina ( $\text{Al}_2\text{O}_3$ ), per cent.....	14.5	6.0
Lime ( $\text{CaO}$ ), per cent.....	42.0	1.5
Magnesia ( $\text{MgO}$ ), per cent.....	2.0	0.5
Sulphur (S), per cent.....	1.0	.....
Melting point, deg. Cent.....	1260	1260

The fineness of the slag is such as to pass a 40-mesh sieve. The bricks are kept at a temperature of 1350° C. for two hours after the slag is added, at the end of which time the furnace is allowed to cool, or the bricks may be removed from the furnace and allowed to cool in air. The bricks when cold are sawed lengthwise at a right angle to the unbranded side, so that one side of the cutting wheel cuts through the center of the drilled cavity, and this area of slag penetration, together with the cavity, is measured with a planimeter. The area of the original cavity is subtracted, giving the result in square inches of slag penetration. The wheel used for sawing the brick is a carborundum wheel 12 in. in diameter;  $\frac{1}{8}$  in. thick;  $1\frac{1}{2}$ -in. center hole; grit 16; bond NCH.

#### SOFTENING TEST

*Operation of Test.*—The test specimens for determining the softening temperature are cut by means of the saw used in slagging test from the corner of the brick, in the shape of a triangular pyramid similar to that of a Seger cone. They are 3 in. high, and the base should not be less than 1 in. on the side. The test specimen, together with a series of Seger cones, is set in some good refractory material which will not flux with the sample. The series of cones used includes numbers both below and above the cone at which the sample is supposed to soften. The whole is placed in a gas-fired furnace and heated at a uniform rate, not to exceed 600° C. per hour. The softening temperature is considered that at which the specimen either bends double, sags, or puffs out of shape and is determined by Seger cones.

#### EXPANSION AND CONTRACTION

*Construction of Apparatus.*—The machine used for the measurement of expansion and contraction consists of a micrometer mounted on a steel post, which in turn is mounted on a steel plate 24 by 6 by  $\frac{1}{2}$  in. To the stem of the micrometer is fastened a steel disk 1 in. in diameter and  $\frac{1}{8}$  in. thick. In line with the micrometer is a second steel post on which is mounted a  $\frac{1}{4}$ -in. sliding steel rod with a similar circular disk, as with the micrometer. The rod can be adjusted so as to determine measurements up to 14 in. To insure that this rod is properly set, standard bars 3, 5, 9, 11 and 13 in. long are used.

*Operation of Test.*—In preparing the brick for the test

the ends of the brick are ground so as to be parallel to each other at right angles to the sides. The length is then measured cold. The brick is then heated as in the compression test—or as for the impact test in the case of top-wall and pile brick—removed from the furnace and measured hot. The removing from the furnace and measuring usually requires about 30 seconds. The result is calculated to inches per linear foot.

#### SIZE

*Operation of Test.*—The size is determined by the use of the micrometer described under expansion and contraction. All measurements are made while the brick is at atmospheric temperature. Small particles of sand, clay or foreign matter adhering to the brick are removed before measuring. The locations for taking the measurements are shown in Fig. 16. If the bricks are of a different size than a standard 9-in. brick, the measurements are made in the same way, but at a point of one-fourth of their respective dimensions.

### Synopsis of Recent Chemical and Metallurgical Literature

#### Gold and Silver

**Oxidation of Soluble Sulphides in Cyanide Solutions.**—In the course of experimental work on leaching roasted ore with cyanide solution, H. R. EDMANDS gave attention to solutions foul with soluble sulphides and the oxidation of those compounds. His results are recorded in the April *Journal* of the Chamber of Mines of Western Australia. The general impression has been that soluble compounds were very unstable, disappearing on decantation from one vessel to another, if they are not already precipitated by the zinc always present in mill solutions. Results showed that their proneness to oxidation has been overestimated and that the presence or absence of protective alkalinity has little effect on their oxidation, but that soluble carbonates tend to hasten oxidation. A more effective oxidation occurs in the leaching vats where, after draining, a strong oxidizing effect is given by included air, assisted by the presence of ferric oxide.

**Effect of Lead Salts in Cyanide Treatment.**—The same author gives results of solvent activity tests, using various solutions on pure gold and roasted ore. For the pure gold tests he used a plate of metal of 9 sq. cm. total area, and agitated it for 16 hours in a stoppered bottle of 344 cc. capacity, with 200 cc. of the solution to be tested, thus leaving 144 cc. of air containing about 0.038 g. oxygen, or sufficient for the oxidation of 945.6 mg. gold. In addition the effect of adding lead acetate to solutions containing soluble sulphides was determined and from this it appears that if the precipitated sulphide be removed by filtration a considerable increase in solvent activity ensues, but that the presence of PbS renders solutions carrying any protective alkalinity almost incapable of dissolving gold, which power is only imperfectly restored by neutralizing the protective alkalinity.

Experiments made on the roasted ore showed that the addition of CaO improved extraction; adding lead acetate in addition to CaO gave a further improvement; but the best extractions were obtained by adding acetate and omitting lime, at a cost, however, of greater cyanide consumption.

It should be noted that in these tests no soluble sulphides were detected either before or after treatment.

Somewhat different results were obtained by two following tests, in which roasted ore was agitated with solution foul with soluble sulphides,



A. Solution contained 0.0036 per cent soluble sulphides in terms of  $K_2S$ , 8 lb.  $CaO$  added per ton ore, and excess air present.

	Residue
(1) Amount acetate added, twice that required to precipitate all $K_2S$ .....	17s. 6d.
(2) Acetate sufficient to precipitate all $K_2S$ , no excess.....	10s. 6d.
(3) No acetate used.....	8s. 6d.

B. Solution contained 0.0023 per cent soluble sulphides, in terms of  $K_2S$ , no  $CaO$  added, but solution on already contained 0.019 per cent  $CaO$ .

	Residue
(1) Excess air present.....	15s. 0d.
(2) No excess air, air excluded.....	30s. 0d.
(3) Excess air, acetate to precipitate all sol. sulphides, but no excess.....	8s. 0d.

Solutions off contained no protective alkalinity, and except No. 2 were free from  $K_2S$ .

It would appear that under these conditions, in a solution containing little or no protective alkali, the use of acetate in just sufficient quantity to precipitate soluble sulphides, is beneficial but may be injurious in the presence of much  $CaO$ , especially if the acetate be in excess.

### Cement and Concrete

**Tricalcic Silicate in Portland Cement.**—According to a paper published by GEORGE A. RANKIN in the *Journal of the Franklin Institute*, the major constituents of Portland cement are tricalcic silicate, dicalcic silicate and tricalcic aluminate. Of these the compound tricalcic silicate is the one that hardens and develops the greatest strength within a reasonable time. While most important, this compound also is the one most difficulty formed, and comprises but 30 to 35 per cent of an average normal Portland cement. It may be said, therefore, that the essential process for the manufacture of Portland cement is the formation of this compound and that any improvement in the process which will increase the percentage of this constituent will add to the cementing value of the product. In order to determine the most economical process for producing this compound in higher percentages, it will be necessary to study the rate of its formation in a series of mixtures of various substances. It will be necessary also to determine the equilibrium relations of the compound at high temperatures in such mixtures. A scientific investigation of this kind will lead sooner to the discovery of the best composition than the empirical cut-and-try methods.

**Specification for Concrete Aggregates.**—Instead of specifying that concrete aggregates, especially sand, be of a certain fixed minimum standard of quality, which may not be attained in certain localities, it is proposed by C. M. CHAPMAN in *Engineering Record*, July 8, that the specifications shall read about as follows: "The materials used shall be of such quality and shall be used in such proportions, as to produce a concrete which shall show a compressive strength of 2500 (or 2000 or 1500) lb. per square inch at the age of 28 days, when tested according to standard methods." The author contends that specifications should be drawn to insure the production of suitable concrete if the aggregates are properly used and should permit of the use of local materials when they are capable of producing concrete of the required quality. It is better to specify the result required than to handicap the builder with specifications as to material which he cannot fulfill.

It is assumed, for instance, that for mass foundations and footings, retaining walls, abutments and similar service, a concrete of compressive strength of 1500 lb. per square inch at age 28 days is suitable. For reinforced walls and matts where stresses are moderate a compressive strength of 2000 lb. may be required,

while for reinforced floor slabs, beams, girders, columns, etc., a minimum compressive strength of 2500 lb. may be necessary. By specifying the results required and permitting the use of such materials as will produce these results when tested under specified standard conditions, it is possible not only to safeguard the products but to permit the use of locally available materials. In operating under such specifications it is important to test specimens of concrete produced on the job and check the quality of materials used so as to insure reasonable uniformity.

### Distillation

**Operation and Costs of an Eight-Effect Distilling Plant.**—The number of bodies or effects in commercial distilling plants varies from one to twenty-four, this number having been proposed, although installations having more than eight are rare. In the *Journal of the Engineers Club of Baltimore*, June, 1916, FRANK T. LEILICH gives a description of an eight-effect salt-water distilling plant of the Lillie type. It is designed particularly for use in ice-making plants, bottling establishments and marine service.

The present tests were made on a plant installed in an isolated fortification where fuel is expensive and storage facilities limited. Diesel engine prime movers are employed and the boilers furnishing the steam for the distilling plant are fired with fuel oil. The plant was designed to meet specifications calling for 5000 gal. per day of distilled water. The average production was to be not less than 6 lb. for every 1177 B.t.u. of total heat above 32 deg. Fahr. contained in the steam supplied and a thirty-day demonstration was to be made.

The pressure ranges decided upon were 10 lb. gage to 24 in. vacuum. The shell and heads were made of cast iron, both heads being hinged, and the steam tubes were of copper. The plant was arranged to be operated with either half as a quadruple effect and both halves reversible.

During the preliminary tests the steam quality was determined by means of a throttling calorimeter. Later this instrument was rendered unserviceable by an accident, and as the contractor agreed to accept the test results on the assumption that the steam supplied contained no moisture, the damaged calorimeter was not replaced. The exhaust from the condenser pump and a condenser cooling water pump furnished nearly all of the steam required for octuple running. These pumps and the make-up passing through the reducing valve were supplied with steam at 90 to 100 lb. gage by two hoisting engine boilers.

During the first few weeks of running, the operation of the plant was not satisfactory, as the condenser pump proved to be too small and the performance of the apparatus was spasmodic. However, the purity of the distillate produced was as good as required by the specifications. Several sizes of pumps were tried before one suited to the service was secured. While experimenting with the pumps various modifications of the gas removal connections were tested out, but with the proper size of condenser pump the original connections were found to be most satisfactory. In addition to the pump and gas accumulation troubles, the removal of the condensation from the steam end No. 8, working with No. 1 hottest, was neither regular nor positive. This caused irregular discharge and reduced the rate of working, as the tubes in No. 8 would become flooded. In the opinion of the author both of the above difficulties can be traced primarily to the small pressure drop in the effects. In his opinion, a plant operating between the pressure ranges of 10 lb. gage and 24 in.

vacuum should not have more than six effects. When either half of the plant was operated quadruple, no trouble was experienced, which seems to substantiate the above view. After considerable experimenting, what might be termed an equalizer pipe running under the effects was installed connecting the condensation discharge at No. 8 with the condensation connection into the condenser. After the installation of this line, the pump removed the condensation from No. 8 as fast as it accumulated and the plant ran at a uniform rate.

The thirty-day run was started on Nov. 9, 1914, the plant being operated by three shifts of two men each. The operators were required to make hourly records of the readings of the various gages and thermometers connected with the apparatus.

When the apparatus was shut down at the end of the thirty-day run the heads were opened and the scale formations carefully examined. The tubes were coated with a substance resembling common salt, the coating being about as thick as an ordinary visiting card. Most of the coating could be scraped off with a small stick. The deposit was not analyzed, but a sample that was put into dilute hydrochloric acid was almost completely dissolved. After the completion of the thirty-day run, and without cleaning the tubes, several economy tests were made. The results of a few of these are summarized in Table I.

quires considerable care in order to prevent "pulling over" salt water. Carrying the brine levels too high also results in a salty product. These levels are not maintained automatically, but with uniform supply pressures an experienced operator can readily find by trial the proper setting of the four-way feed cocks for continuous feeding of the apparatus.

The Lillie apparatus is especially adapted to installations where a supply of exhaust steam is available and where fuel costs require that the distillation be carried out with a minimum expenditure of heat. As regards scale formations, the Lillie plant will show to best advantage when the distillation is from sea water or other source approaching this in character. While a six or eight effect reversible plant is somewhat more complicated than the more common types of evaporators, experience has demonstrated that employees of average intelligence can, in a few weeks, become proficient in the operation of the apparatus. As usually built, the effects are arranged horizontally and hence require considerable floor space for the installation.

The cost of a plant will, of course, be dependent upon the capacity and other circumstances connected with the proposed installation. The plant described in this paper is for installation on a military post and hence the operating costs have but little commercial significance. Assuming, however, the equipment would be used com-

TABLE I

Test No.	Date	TIME		TIME		READINGS OF GAGES ON EFFECTS								Vac. Cond.	Lb. Dist. per Lb. of Steam*	GALLONS		Lb. Dist. per Lb. of Steam	Daily Rate, Gallons	Remarks
		Start, P.M.	Finish, P.M.	Reverse, P.M.	Min. Rqd.	1	2	3	4	5	6	7	8			Steam	Total Out-put			
1	1-14-15	1.15	4.15	2.38	10	21.8"	17."	12.4"	9.2"	5."	0.6"	2.1"	5.2"	24.1"	6.2	127	941	7.4	7500	Salt water "pulled over" during reversal. 1 bbl. of dist. thrown away. Room 64° F.
						5.3"	1.1"	2.9"	8.1"	11.4"	15.2"	18.7"	22.9"	24.8"	8.3					
5	1-22-15	4.35	9.10	6.38	10	5.3"	1.3"	4.1"	8.3"	12.7"	16.8"	20."	24."	25.6"	6.2	222	1332	6.0	7000	Brine pulled down four times Room, 66° F. Feed, 55° F.
						21.2"	15.3"	11.7"	7.6"	3.6"	0.6"	2.1"	4.9"	24.6"	5.7					
6	1-22-15	9.35	10.08							19."	11.5"	4.4"	1.8"	24.1"	5.2	36	186	5.2*	7600†	"

\*Effect of reversal not included.

†Calculated on a basis of 6 reversals per day, 23 hours of full capacity running.

After making several economy runs, it was found that the output per pound of steam depended considerably upon the care in operation, and individual results were difficult to reproduce.

During all tests the distillate was sampled at regular intervals. Grab samples of about 25 c.c. were taken and all samples taken during a test were poured into a clean bottle which was kept securely corked. The contents of the bottle were assumed to represent the average quality of the distillate produced during the run. The samples were tested for chlorine only. The results of the analysis of a few of the samples are given in Table II below.

TABLE II				
Test No.	Date (1915)	Operating	Aver. gr. of Cl per gal.	Aver. of 4 determ.
1	Jan. 14	Octuple	.806	" " " "
2	Jan. 15	Octuple	.731	" " " "
3	Jan. 16	Quadruple	2.510	" " " "
4	Jan. 22	Octuple	.76	" " " "

These analyses are believed to be representative of what the apparatus will do when attended by a skillful operator. The men employed as operators during the test had no previous experience with the apparatus and worked under the supervision of the contractor's representative. After operating under these conditions for about four weeks two of the men could be depended upon to handle the plant satisfactorily. Reversing re-

merically the costs would probably be about as set forth in Table III below.

TABLE III—FIXED CHARGES AND OPERATING COSTS

A—Fixed charges (based on an investment of \$16,500 for eight-effect distilling plant complete with boilers and auxiliaries).		
Interest, 6%.....		\$990.00
Insurance and taxes, 1%.....		165.00
Depreciation, 5% .....		825.00
Total.....		\$1,980.00
B—Operating costs (based on operation for 300 days per year).		
Labor, one operator at \$60 monthly.....		\$720.00
Repairs and maintenance, estimated at 3% of first cost .....		495.00
Fuel—Coal at \$3.50 per ton (assumption:—8 lbs. of steam per lb. of coal, 6 lbs. of distillate per lb. of steam, 9 hours daily operation at rate of 7,000 gals. in 24 hours, 12% allowance for steam used in warming up, leakage, etc.).....		270.00
Total.....		\$1,485.00
C—Operating costs based on operation for 300 days, 24 hours per day.		
Labor—Three operators at \$60 each monthly.....		\$2,160.00
Repairs and maintenance—estimated at 3% of first cost .....		495.00
Fuel—Coal at \$3.50 per ton (assumptions:—8 lbs. of steam per lb. of coal, 6 lbs. of distillate per lb. of steam, 7,000 gals. daily output, 8% allowance for steam used in warming up, leakage, etc.).....		690.00
Total.....		\$3,345.00
Summary:		
Total costs, (A) plus (B).....		\$3,465.00
Yearly output (300 days of 9 hours), gallons.....		787,000
Cost per gallon.....		.0044
Total costs, (A) plus (C).....		\$3,325.00
Yearly output (300 days of 24 hours), gallons.....		2,100,000
Cost per gallon.....		.0025



The above cost estimates are of necessity only rough approximations. The capital investment, it should be noted, includes the cost of boilers, etc., and is perhaps higher than it would be for an ordinary commercial plant. Operating costs do not include labor of a fireman, it being assumed that the increased load of the distilling plant could be handled without an increase in the fire-room force. This is a fair assumption, as the distilling plant attendants would have sufficient spare time to render service in other ways that would at least balance any fire-room labor charges.

## Recent Chemical and Metallurgical Patents

### Cyanides and Cyanamid

**Production of Cyanogen Compounds.**—An electric furnace process of producing cyanogen compounds and ammonia is patented by AXEL R. LINDBLAD, of Ludvika,

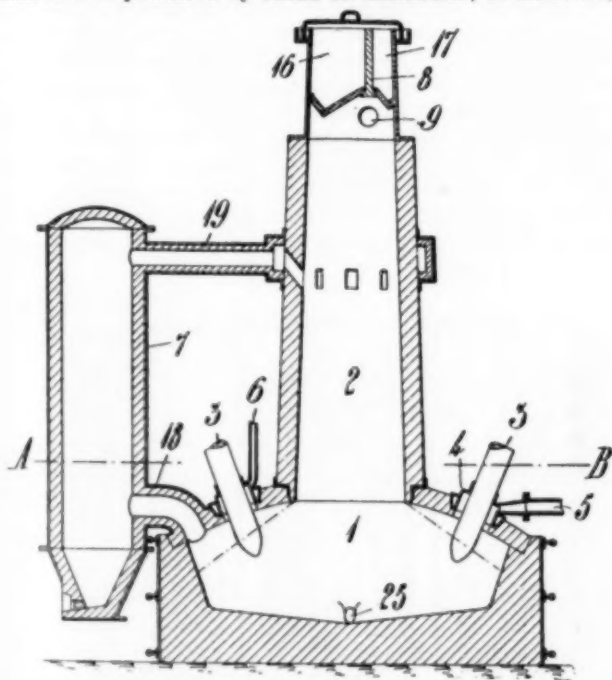


FIG. 1—CYANIDE AND AMMONIA FURNACE

Sweden. A cross-section of the furnace is shown in Fig. 1. In the manufacture of cyanides; potassium or sodium carbonate, or their hydroxides may be used. One of these is charged into the furnace through hopper section 8. Charcoal is fed in at 16, and nitrogen or a nitrogen containing gas is introduced around the electrode 3 at 5. As the charge enters the reaction zone 1, the carbonate is converted into cyanide. It is necessary to charge the potassium carbonate at the side of the furnace on which the nitrogen gas is introduced. The electrodes 3, which supply the heat necessary to carry on the reaction are water-cooled, and the introducing of the nitrogen gas around the electrode also aids in cooling. The temperature of the furnace is raised sufficiently high to gasify the cyanide formed, and any potassium carbonate which is gasified has to pass through the glowing carbon before reaching the gas outlet 18, since the carbonate is charged in the opposite side of the furnace. The gases are led to a condenser 7; where the cyanide is condensed. The gases not condensed are led back to the furnace through line 19. Any slag formed from the ash of the charcoal or other ingredients is tapped at 25.

Barium compounds may also be made, if necessary modifications are made in view of the higher melting points of the raw barium materials.

In the synthesis of ammonia by this method which has been tried before with little success, the cyanide is an intermediate product. The cyanide, formed as described above, except with the use of KOH instead of  $K_2CO_3$ , is led in the gaseous state through chamber 18, without condensing, and led back to the furnace shaft at a higher level through conduit 19, where it meets steam introduced through a jet. The cyanide is decomposed, and the KOH regenerated with the formation of ammonia. The KOH passes through the process again while the ammonia is led off through the tap.

Auxiliary electrodes may be used at a point near the introduction of the cyanide gas and the steam to facilitate the reaction. (1,186,921, June 13, 1916.)

**Production of Calcium Cyanamid.**—In the production of calcium cyanamid from calcium carbide and nitrogen it has been found desirable to keep the temperature as low as possible due to the reversibility of the cyanide reaction. The reaction temperature has been reduced by the aid of catalytic substances such as calcium chloride or calcium fluoride. Another reason for the maintaining of as low a reaction temperature as possible was that undesirable sintering and dissociation took place at a temperature a few hundred degrees above the normal reaction temperature, and this temperature might easily be reached on account of the reaction being exothermic. According to a patent of JOHAN HJALMAR LIDHOLM, of London, England, a temperature considerably in excess of the sintering temperature may be used without a corresponding increase in dissociation if the carbide is passed rapidly through an atmosphere of nitrogen and cooled quickly.

A temperature of 2000 deg. C., is used in an electric furnace constructed as shown in Fig. 2. The furnace consists of a tube made of carbon having at its upper end a feeding hopper 4, with screen 5 to sift the par-

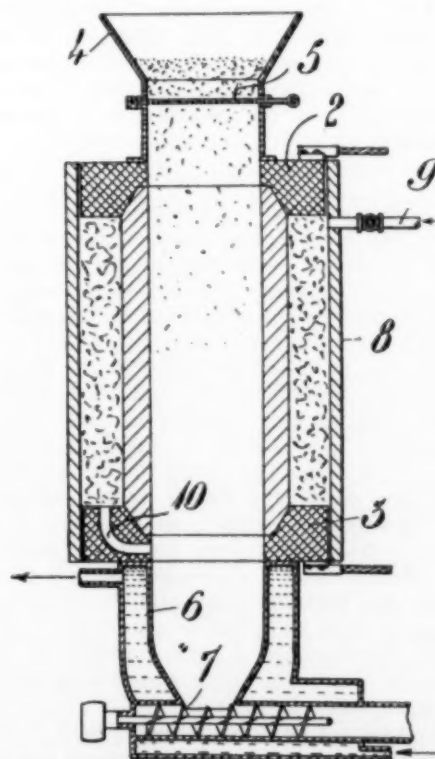


FIG. 2—CALCIUM CYANAMID FURNACE

ticles down into the furnace. The furnace is heated by resistance from contact blocks 2 and 3. At the bottom of the furnace is a water-cooled metal section 6 through which the newly formed cyanamid passes to a screw

conveyor 7, by which it is conveyed from the furnace. The nitrogen is introduced through pipe 9 into a space between the outside shell 8, and the furnace tube. This space is filled with coke and serves to preheat the nitrogen and abstract any oxygen contained therein. It is claimed that yields approaching very closely to theoretical may be obtained by this method. (1,184,109, May 23, 1916.)

#### Flotation Machine

An apparatus for applying the oil-flotation process, known in the industry as the K & K machine, is patented by FREDERICK B. KOLLBERG and MAX KRAUT, of Bisbee, Ariz. It is shown in vertical transverse section in Fig. 3. It consists of a revolvable cylinder or drum

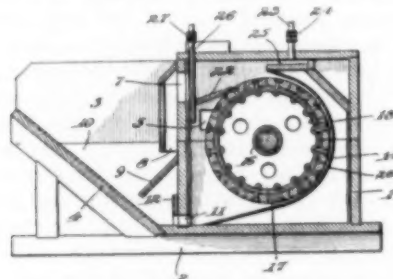


FIG. 3—FLOTATION MACHINE

14, covered with cleats forming longitudinal riffles, moving anti-clock-wise in a close housing in a spraying chamber 1. Ore-pulp to be treated is admitted through opening 5. The spraying chamber has connection with the frothing chamber 3 by way of openings 7 and 8. Air supply pipes 23 communicate with the upper end of the spraying chamber, and oil supply pipes 26 communicate with the interior of the same. In operation pulp exists in the spraying chamber to such a depth that the drum is slightly immersed. In rotation of the drum a certain portion of pulp adheres and is carried around and thrown by centrifugal force through the openings 7. Ample opportunity is afforded for complete aeration and oiling of the pulp by the rapid revolution of the drum. (1,174,737, March 7, 1916.)

#### Welding

**Welding Scrap Nickel Anodes.**—In nickel plating work, after the anodes have been consumed to the extent of 75 to 85 per cent they become ineffective and new anodes must be used. The old anodes are scrapped and returned to the manufacturers to be remelted and recast. In a novel process patented by JAMES J. WALSH of Indianapolis, Ind., and assigned to the Prest-O-Lite Company, Inc., of Indianapolis, Ind., it is proposed to weld these scrap anodes together and use them again as new anodes. The welding is done by the oxy-acetylene flame, by heating two scrap anodes to the fusing point and then depositing hotter molten nickel on the joint, thus building up a homogeneous joint. A number of anodes are thus joined until the size is sufficient for use in the plating bath. (1,185,959, June 6, 1916.)

**Alloy for Arc Welding.**—An alloy to be used in the arc welding of iron and steel is patented by DAVID H. WILSON, of Paterson, N. J., and SANSOM M. RODGERS of Pittsburgh, Pa. The alloy consists of iron, manganese, copper, and carbon; successful proportions being 0.60 to 1.00 per cent manganese; 0.25 to 0.40 per cent copper, 0.18 per cent or less of carbon and the balance, iron. With these proportions a desirable voltage is 35 with electrodes 0.15 in. in diameter. The excess of manganese and copper, over the amount burned out in the arc has the effect of preserving the strength of the weld to a greater extent than formerly. The manganese protects the carbon and the iron, and the copper

reduces the melting point of the alloy and thus the welding temperature. It has been found desirable to weld at the lowest temperature possible, as the welding metal is less affected by the arc, flows more evenly and makes a better weld. (1,187,411-12, June 13, 1916.)

#### Sodium and Alkali Metals

**Electrolysis of Fused Alkali Chlorides.**—An apparatus for the production of alkali metals from alkali chlorides such as sodium from sodium chloride is patented by JOHANNES PFLEGER and FRIEDRICH OTT, of Frankfort-on-Main, Germany, and assigned to the Roessler and Hasslacher Chemical Company of New York. The apparatus is similar to the Castner apparatus in which fused caustic alkali is electrolyzed with the production of sodium. The application of the Castner apparatus to the electrolysis of sodium chloride has been previously tried and was the subject of German Patent No. 236,804. In this patent it was proposed to use two partitions separated from each other, made from different materials for the separation of the products by electrolysis. This scheme was, however, too complicated.

In the present patent it is claimed that all that is necessary is to make the part of the apparatus which is subject to chlorine gas, proof against this gas, and then the sodium chloride may be successfully electrolyzed. A diagram of the apparatus as so arranged is shown in Fig. 4. A receptacle A, of iron serves as a

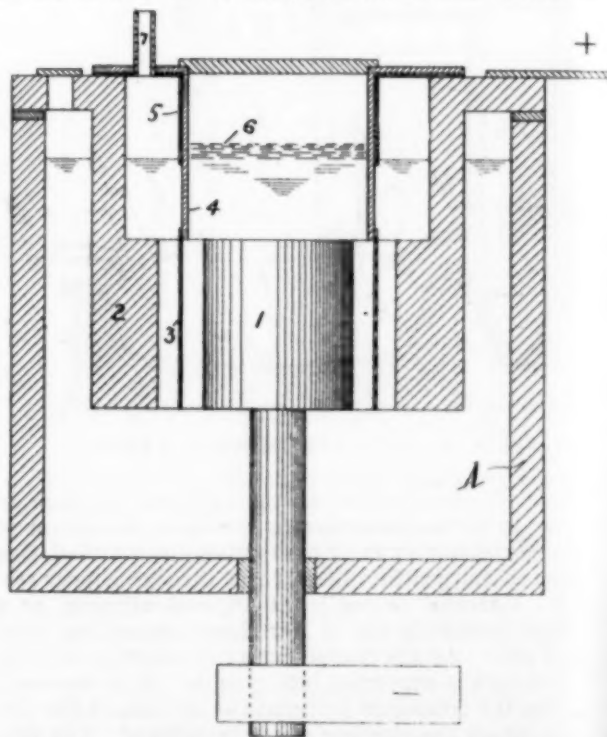


FIG. 4—CROSS-SECTION OF ELECTROLYTIC APPARATUS

container for the electrolyte and electrodes. The cathode 1, is of iron and the anode 2, of carbon. The electrodes are separated by a wire screen 3, which is connected with an iron receptacle 4, covered at the top. The outside of this iron receptacle is covered by a preparation 5, which is not attacked by chlorine gas. This preparation consists of asbestos thread impregnated with a thin paste-like mixture of water, glass and asbestos flour. This is wound around the vessel, and is ready for use when dry. The use of solidified salt as the chlorine resisting material is the subject of a second patent. In the operation of the cell the sodium formed collects at the cathode in 4. The chlorine escapes through pipe 7. (1,186,936, June 13, 1916.)



## A Pneumatic Powdered Coal System

The use of powdered coal as a fuel has received very considerable attention in the metallurgical industries during the last few years; after, in the Portland cement industry, it had found a wide application for a long time.

tance from the furnaces, and it is necessary that the distributing system be efficient.

The essential features of the Holbeck system are shown in Fig. 1. Bituminous crushed, nut or slack coal is stored in a bin, preferably made of steel or concrete. The coal passes from the bin and an automatic

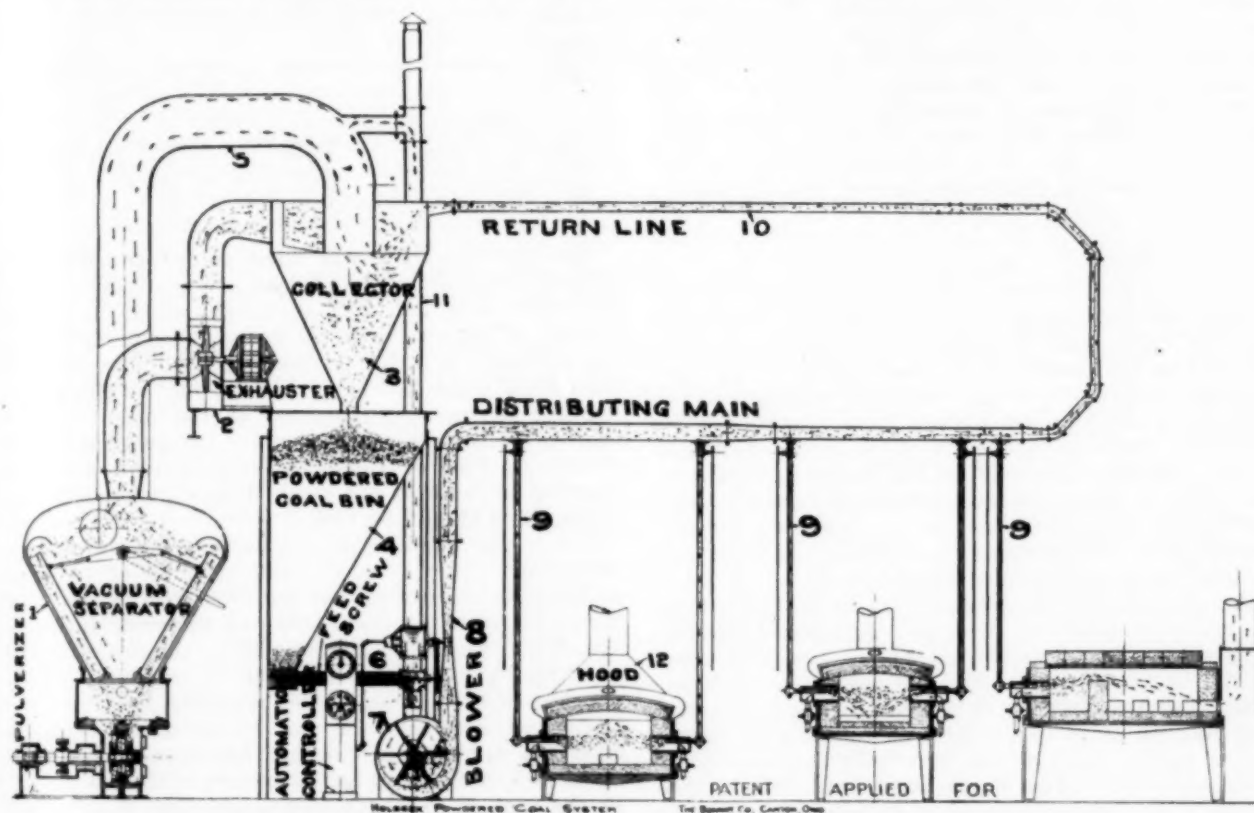


FIG. 1—DIAGRAM OF POWDERED COAL SYSTEM

For reverberatory furnaces powdered fuel is used on a large scale at Copper Cliff and Anaconda.

For metal heating furnaces an interesting system has been developed by A. A. HOLBECK of the Bonnot Company, Canton, Ohio. This system, which is supplied by the Bonnot Company, makes it possible to distribute the fuel to widely scattered furnaces. The coal-pulverizing plant is necessarily located some dis-

feeder regulates the amount of coal fed to the pulverizer, shown at the extreme left. As the coal becomes pulverized it is thrown up into the vacuum separator 1 by the action of the pulverizer. This separator separates the fine particles of coal dust from the coarse, the finest being drawn into the exhaustor 2, the coarse falling down into the pulverizer.

From the exhaustor 2 the powdered coal is blown into the collector 3. The expansion of the air as it enters the collector permits the coal dust that is carried in suspension to fall to the bottom of the collector and into the coal storage tank 4. The air that enters the collector returns through pipe 5 to the pulverizer to be used over again.

The coal dust is taken from the storage tank 4 by the feed screw 6 and delivered into the suction side of high-pressure blower 7. It is then blown into the distributing main 8, and carried to the furnace through the distributing pipes 9.

The coal which is not used at the furnaces is returned through the return line 10 to the collector 3, where it is extracted from the air and falls into the coal storage tank 4 to be used over again.

The air after the coal is extracted is returned to the suction side of the blower through pipe 11. The products of combustion from the furnaces are collected by the hoods 12 placed in front of each furnace, and are disposed of either by means of an exhaustor or a stack.

In Fig. 2 is shown an ingot-heating forge furnace equipped with this system, showing the powdered coal connections and burners.



FIG. 2—INGOT HEATING FORGE FURNACE EQUIPPED FOR POWDERED COAL BURNING

## A Comparison of Oxy-Hydrogen and Oxy-Acetylene Cutting

BY WALTER P. SCHUCK

The recent installation throughout the country of plants producing oxygen by the electrolytic process has resulted in many cases in the production of a comparatively large amount of pure hydrogen as a by-product. The uses to which this hydrogen can be put are consequently of commercial importance. It has been well known that hydrogen in connection with oxygen is essential for cutting thick plates of steel. For cutting steel plates up to about 5 in. thick acetylene can be used for the pre-heating flame, but heavier sections require the use of hydrogen.

Even with this known advantage of hydrogen there are fewer makes of cutting torches adapted to the use of hydrogen with oxygen than those adapted to the use of acetylene with oxygen. This is probably due to the fact that hydrogen is less extensively used with oxygen for welding than acetylene, and most cutting torches are developed by makers of oxy-acetylene welding torches. Recently a combination cutting torch, known as the "Modern," that can be used with either oxy-hydrogen or oxy-acetylene by changing the tips, was developed, and while it does good work with acetylene the trials showed the use of hydrogen to be so much more economical that the writer was requested to observe a series of tests and measure the gas used.

The procedure in these tests was to first determine the minimum pressure of oxygen that would satisfactorily cut the thickness of steel on trial, and then measure the speed of cutting and the amount of each gas used. The pre-heating gas, whether hydrogen or acetylene, was delivered to the torch at the pressure necessary to maintain the proper flame with the valve at the torch wide open. The oxygen used in connection with hydrogen or acetylene for the pre-heating flame had to be regulated by means of the valve on the oxygen line at the torch, because the oxygen pressure in the hose to the torch had to be heavy enough to do the cutting required. After the proper oxygen pressure had been determined a convenient length of cut was made and timed by taking the time from the instant the cutting jet of oxygen was started until the cut in the steel was finished.

The oxygen used for each thickness of steel was measured by a counterpoised gas meter, by shutting off the hydrogen or acetylene at the torch and leaving the

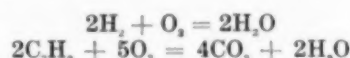
In terms of the amount of gas used per lineal foot of cut and the cost of cutting, these data present some very interesting facts as shown by Table II.

TABLE II  
Gases Used per Lineal Foot of Cut, and Cost of Gases per Lineal Foot.

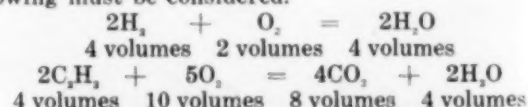
Thickness of Steel, Inch	Oxy-hydro.	Oxy-acety.	Oxy-acety. (Acet. 1c)	Oxy-Acety. Oxygen Only
$\frac{1}{4}$	\$0.016	\$0.043	\$0.034	\$0.027
$\frac{1}{2}$	0.037	0.096	0.078	0.064
1	0.071	0.165	0.142	0.124
$1\frac{1}{2}$	0.093	0.215	0.187	0.164
2	0.114	0.291	0.250	0.230

The cost of oxygen was taken at 2c. per cubic foot, hydrogen at  $1\frac{1}{2}$ c. per cubic foot, and acetylene at  $2\frac{1}{4}$ c. per cubic foot, and also at 1c. per cubic foot. The amount of oxygen required when using acetylene as the source of heat for pre-heating is so much greater than when using hydrogen that it would be cheaper to use the oxy-hydrogen process at the prices named, than to use oxy-acetylene even if the acetylene were obtainable free of cost. This seems such a strong showing in favor of the oxy-hydrogen cutting that an explanation should be had.

The writer believes that in view of the well-known deleterious effect of even small amounts of the non-combustible gases when cutting steel with oxygen (see Tucker, *Journal of the Society of Chemical Industry*, Vol. XXX, page 779, July 15, 1911) the low efficiency of oxy-acetylene cutting can well be explained by the presence of the carbon dioxide resulting from the combustion of acetylene. A part of the gases resulting from the combustion of either hydrogen or acetylene are drawn into the cut by the suction of the oxygen jet. In the case of hydrogen this means that water vapor and nothing else will dilute the oxygen used for cutting, while with acetylene both carbon dioxide and water vapor are introduced. This is clearly shown by the chemical equation of the union of these gases with oxygen.



These equations, however, show only the molecular relation of the combustion of these gases, and for a true understanding of the amount of carbon dioxide involved the volumes entering into the reaction as shown in the following must be considered.



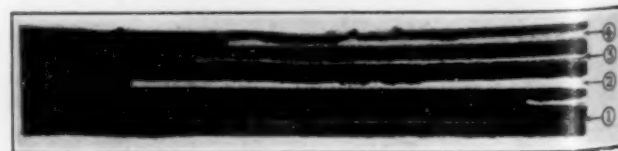
In short, this means that the complete combustion of one volume of hydrogen produces one volume of water vapor, while acetylene produces its own volume of water vapor plus twice its volume of carbon dioxide. This additional carbon dioxide dilutes the cutting jet of oxygen to such an extent that a great deal more must be used than is necessary when burning hydrogen.

The gases used in these tests were: electrolytic oxygen 99.5 per cent pure, electrolytic hydrogen 99.8 per cent pure, and acetylene from a commercial tank of com-

TABLE I

Thickness of Metal, Inch	CUTTING SPEED FT. PER HR.		PRESSURES AT WHICH GASES ARE USED				GAS CONSUMPTION, CUBIC FT. PER HR.			
	Oxy-hydro.	Oxy-acety.	Oxy.	Hydro.	Oxy.	Acety.	Oxy.	Hydro.	Oxy.	Acety.
$\frac{1}{4}$	90	103	3	2	12	10	47	35	140	71
$\frac{1}{2}$	45	50	5	2	15	10	56	35	160	71
1	40	30	12	5	35	10	90	71	242	71
$1\frac{1}{2}$	33 $\frac{1}{2}$	32	15	5	40	10	104	71	263	71
2	30	28	20	5	55	10	123	71	327	71

oxygen flow from the torch just as it had while making the cut. To guard against any back pressure in the gas meter, due to friction, a water-filled U-gage was connected to the intake pipe of the gas meter and the water in it kept level during the passage of the gas and when it was measured. The hydrogen and acetylene were measured in the same way after the flame had been relighted, adjusted and then the oxygen shut off and the flame extinguished by putting the torch under water. Table I gives the data derived from these tests.



CUTTING TESTS



pressed gas held in solution by acetone. These tests were all made using the torch moved by hand along a guide and represent fair average practice with the equipment mentioned. With gases of poorer quality, such as oxygen made from air, the speeds given can not be maintained and greater pressures must be used.

A trial of cutting 1-in. steel plate was made using atmospheric oxygen with hydrogen and also with acetylene, and the results are clearly shown in the accompanying photograph. Each of cuts numbered 1, 2, 3 and 4 represents the longest cut possible to make in this material in two minutes, using the same size cutting tip and the least pressure of oxygen that will make a thorough cut. Cut No. 1 was made with electrolytic oxygen 99.5 per cent pure and electrolytic hydrogen. Cut No. 2 was made with electrolytic oxygen 99.5 per cent pure and acetylene. Cut No. 3 was made with atmospheric oxygen 97.4 per cent pure and electrolytic hydrogen. Cut No. 4 was made with atmospheric oxygen 97.4 per cent pure and acetylene. All previous cuts were covered and not visible to the operator when making a cut.

Portland, Oregon.

### Personal

Mr. David F. Baker, formerly connected with the blast furnace department of the Broken Hill Proprietary Company at New Castle, New South Wales, is in this country and will take up permanent work here.

Dr. Wallace P. Cohoe has moved his office and laboratory from the Chemists' Building, 50 East Forty-first Street, New York, and has taken an office in the Trinity Building, 111 Broadway. His laboratory has been moved to Bertrand Avenue, Perth Amboy, N. J., where he now has facilities for carrying out investigations under manufacturing conditions.

Mr. F. G. Cottrell was in Denver recently in conference with officials of the Bureau of Mines. He expected to visit Anaconda and other western plants before returning to Washington.

Mr. Noel Cunningham, formerly of the Dorr Company, has opened an office as consulting metallurgical engineer at 200 Fifth Avenue, New York.

Prof. H. O. Hofman, of the Massachusetts Institute of Technology, has been making a trip through the West visiting lead smelters at Chicago, Omaha, East Helena, Northport, Trail, Selby and Tooele.

Mr. W. R. Hulbert, sales manager of the Goldschmidt Thermit Company of New York, delivered an illustrated lecture, supplemented with practical demonstrations, on the theory and practicability of making thermit welds, to the members of the Clinchfield Railway Club, at Erwin, Tenn., on Tuesday evening, July 25.

Mr. Robert M. Keeney has been in Denver on professional business.

Mr. Karl L. Kithil will be in charge of the new station of the Bureau of Mines recently established at Tucson, Ariz. For several years past he has been on the bureau's staff at Denver.

Mr. Van H. Manning, director of the Bureau of Mines, is on a trip of inspection to the western stations of the bureau. He expects to select the location for a northwestern station before his return.

Mr. Ernest B. Nelson, formerly connected with the Chile Exploration Company, Chuquicamata, Chile, has accepted a position with the Andes Exploration Company, Chanaral, Chile.

Mr. Charles Pascoe, formerly metallurgist for the Canadian Steel Foundries, Ltd., and recently connected

with the Thos. Davidson Manufacturing Company, Ltd., of Montreal, as consulting metallurgist, has joined the Snyder Electric Furnace Company of Chicago, Ill., as metallurgist in that company's electric furnace research plant at Clearing, Ill. Mr. Pascoe's work in connection with the Thos. Davidson Manufacturing Company had to do with the production of shell billets from a Snyder electric acid steel furnace. Mr. Douglas Walker, former salesman for the Snyder Electric Furnace Company, and in charge of the Chicago district, has been appointed sales manager.

Mr. W. G. Savage, associated for many years with the Chicago office of the United States Cast Iron Pipe & Foundry Company, has been appointed assistant sales manager in charge of Western territory.

Mr. H. W. Seldon, manager of the metallurgical department of the Scientific Materials Co., Pittsburgh, Pa., has resigned to become assistant to the superintendent of the Franklin Open-Hearth Department of the Cambria Steel Co., at Johnstown, Pa.

Mr. Louis E. Strathman, manager and chief engineer of the pumping department of the Allis-Chalmers Manufacturing Co. of Milwaukee, Wis., was recently elected president of the Engineers Society of Milwaukee.

Mr. Melbert W. Taber, formerly manager of maintenance and construction of the Packard Motor Car Company, has been appointed manager of the Detroit office of the Asbestos Protected Metal Company of Pittsburgh, Pa. The Detroit office is located in the Penobscot Building.

### Industrial Notes

The J. P. Devine Company, Buffalo, N. Y., has recently issued Bulletin 101 describing vacuum chamber dryer units that are adapted for the drying of materials that can be handled on trays or pans; Bulletin 102, describing the Devine vacuum drum dryers, adapted for all liquids and solutions containing solids, drying same to a powder; and Bulletin 103, describing Devine vacuum rotary dryers that are used in connection with drying materials that can be mixed or tumbled in the drying.

The School of Applied Industries of the Carnegie Institute of Technology, Pittsburgh, Pa., has completed its first decade in industrial education and the results have been highly gratifying. Almost 10,000 students have been enrolled at some time or other during these years, 476 of whom have been awarded diploma or certificates of graduation. Four industrial courses covering three years each are offered, viz.: machine construction, building construction, general equipment and installation, and printing. A one-year intensive trade course is also offered. The school has been under the direct charge of Dean Clifford B. Connelley.

**Russian Trade.**—R. Martens & Co., Inc., New York, exporters, are expanding their export operations in Russia. The original purpose of limiting their operations to the mechanical lines of industry will be strictly adhered to. But to conserve the tremendous opportunity for non-mechanical lines, they have created a subsidiary company under the name of "Russia Trade Corporation of America." The new concern will have a complete business organization and its general offices will be in the Maritime Building, 8 and 10 Bridge Street, New York, and all business transactions will be entirely separate and distinct from the parent company.

Messrs. Eimer & Amend, New York City, have filed plans for the new ten-story addition which will be

built to the present store at Third Avenue and Eighteenth Street. The cost will be \$100,000.

**The Improved Equipment Company**, 60 Wall Street, New York, has added a new department, to be known as the Boiler Department. This department will offer its services for the design of steam boiler furnaces, hand fired; automatic stokers, forced-draft equipment for all types of furnaces and stokers; oil, tar and gas burners and complete plants for these fuels; pulverized and crushed coal furnaces and apparatus.

**The Sarco Co., Inc.**, New York, have appointed Newton-Johnson, Sales Engineers, as sales representatives in Wisconsin and the northern peninsula of Michigan.

**The John A. Crowley Co.**, Detroit, Mich., announce the sale of 2 Gronwall-Dixon furnaces which will be installed shortly. One of these furnaces will be used for sheet bars and the second for high-grade tool steel.

**The Titanium Alloy Mfg. Co.**, Niagara Falls, N. Y., has recently added to its bronze department sales force Mr. Gilbert T. Mason, formerly secretary and treasurer of The Atkinson Co., Rochester, N. Y.

**The Colorado Iron Works Company** has issued Pamphlet 24-B describing the Akins classifier, Pamphlet 9-B describing the Impact screen, and Pamphlet 30 describing crushers and rolls.

**The Nash Engineering Co.**, South Norwalk, Conn., has issued Bulletin No. 5, describing the Nash hydro turbine, air compressors and vacuum pumps, single-stage type.

**The American Blower Company**, Detroit, Mich., has issued Bulletin No. 17, series 3, describing "A, B, C" heaters for use in heating, ventilating, and air conditioning work; and Bulletin No. 17 series 4, describing "A, B, C" unit heaters for special work in various industries.

**Instruction Book on Oxy-Acetylene Welding and Cutting.**—A nicely arranged little book has been gotten up by the Prest-O-Lite Co., Inc., of Indianapolis, Ind., on the practice of oxy-acetylene welding and cutting. The authors are H. Sidney Smith and A. F. Brennan. The purpose of the book as stated in its preface is to present, in the simplest language, a brief description of the practical application of oxy-acetylene welding and cutting in the metal trades. It has been written especially for the man with little or no knowledge of the process.

**New Refinery Construction in Baltimore.**—The Baltimore Copper Smelting & Rolling Co., Baltimore, Md., began work Aug. 3, on the construction of an addition to its plant to include 700 tanks. The contract for the lead burning was awarded to H. G. Klink of Whiting, Ind.

**Synthetic Ammonia.**—The Badische Anilin and Soda Fabrik, Ludwigshafen, Germany, has increased production greatly at its new plant producing ammonium sulphate by the Haber process. According to the *Chemical Trade Journal and Chemical Engineer* (London), the large demand for fertilizers in Germany, since the outbreak of the war, due to imports being stopped, is responsible for recent large extensions at this plant, over 2000 men now being employed. Still larger works are now being built near Carbetha, on the Saale, which will employ 6000 persons.

**New Oil Refinery.**—The Sinclair Oil & Refining Corporation plans the construction of an 8-in. pipe line from the Oklahoma fields to Chicago and the erection of two refineries, one at Chicago and the other at some point on the Mississippi River. The pipe line will cost \$8,000,000, the refineries costing about \$2,000,000.

**Warren Webster & Company**, Camden, N. J., has issued a beautifully illustrated catalog describing the Webster vacuum system of steam heating. An outline is given of the development of the apparatus, followed by a description of its design and installation. Other special Webster features are also described, such as feed-water heaters, meters, steam separators, traps and air-conditioning apparatus. A series of photographs of buildings in which Webster apparatus is installed is included.

**Locomotive Cranes.**—The Brown Hoisting Machinery Co., Cleveland, Ohio, has issued an illustrated booklet describing Brownhoist locomotive cranes. These cranes have found application in railway work, contracting, steel, coal, lumber, mining and manufacturing industries. The catalog describes the different operations, showing how and where some of them are used.

**Large Junk Pile in 1915.**—The recovery of secondary metals in 1915, as given in the report of the Geological Survey by J. P. Dunlap, shows a great increase over the 1914 recovery both in amount recovered and in the value of recovered products. The secondary metals include copper, lead, zinc, antimony, tin and aluminium. The value of these metals recovered was \$114,304,930 in 1915 as compared with \$57,039,706 in 1914. The amount recovered was close to 400,000 short tons as compared with about 286,000 short tons in 1914. The high price of metals in 1915 stimulated efforts to save scrap and caused the refiners of scrap to work to the limit of their capacity. Dealers in and smelters and refiners of waste metals experienced the greatest period of prosperity ever known. The statistics of secondary metal recovery are valuable as an adjunct to the primary production as they show the total amount of the metals available for consumption.

SECONDARY METALS RECOVERED IN THE UNITED STATES IN 1914 AND 1915

Metal	1914		1915	
	Quantity (Short Tons)	Value	Quantity (Short Tons)	Value
Secondary copper, including that in alloys other than brass.....	58,556	\$15,435,362	99,937	\$33,498,882
Remelted brass.....	99,038	21,054,300	137,540	40,788,000
Secondary lead.....	29,337	4,762,836	36,400	7,416,000
Recovered lead in alloys.....	31,725		42,500	
Secondary spelter.....	42,969		52,900	
Recovered zinc in alloys other than brass.....	3,914	4,782,066	5,300	14,433,600
Secondary tin.....	4,535		5,250	
Recovered tin in alloys.....	7,912	8,887,158	8,400	10,554,180
Secondary antimony.....	1		2	
Recovered antimony in alloys.....	2,645	444,844	3,100	1,811,568
Secondary aluminum.....	2,791		5,700	
Recovered aluminum in alloys.....	1,731	1,673,140	2,800	5,802,100
.....	.....	57,039,706	.....	114,304,930

## Book Review

**The American Fertilizer Handbook for 1916.** Ninth annual edition. 400 pages; price \$1.00. Philadelphia, Ware Bros. Company.

This is the ninth annual edition of this valuable handbook relating to the fertilizer industry. The directories of fertilizer manufacturers, cottonseed oil mills, allied trades, packers and renderers have been carefully revised up to date. Statistics for 1914 and 1915 of potash and nitrogen products, as furnished by the Geological Survey, are included in the book. Special articles are included on the Cyanamid Industry-World Status, by E. J. Pranke; Preventable Losses in Fertilizer Plants, by S. J. Martenet; Possible Sources of Potash in America, by Frank K. Cameron, and The Sulphuric Acid Industry, by Andrew M. Fairlie.